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MUSCULAR ANATOMY OF THE HIND LIMB
OF THE SEA OTTER (*ENHYDRA LUTRIS*)

By
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FOREWORD

In December 1973 the California Academy of Sciences published Dr. Lot D. Howard's work on the muscular anatomy of the forelimb of the sea otter, *Enhydra lutris* (Howard, 1973). This paper represented the results of several years of detailed dissection and anatomical drawing of the front limb musculature of a unique carnivore that has become specialized for life in a marine environment. As Dr. Howard noted in his introduction, one would expect a mammal that lives in the sea and uses its forelimbs for securing food from the bottom, for breaking shellfish on a rock placed on its abdomen, for elaborate grooming of fur, and for holding the young, to have a high degree of muscular specialization. This did not prove to be so. The anatomical features of the limb show a marked resemblance to those of related land mammals. Its functional specialization is basically a result of bimanual use.

Dr. Howard, prior to his retirement to Pebble Beach on the Monterey Peninsula of California, was a world-renowned hand surgeon who had spent years on the staff of Stanford University Medical School. Much of his time in his later years was devoted to watching sea otters in the ocean in front of his home as well as to the anatomical dissection of these animals. Following the completion of his manuscript on the front limb of the sea otter, Dr. Howard began work on the muscular anatomy of the hind limb. Knowing of his own fatal illness, he worked against time to try to complete the dissections and drawings which are presented in this paper and at the time of his death the work was nearly finished. Mr. Judson E. Vandever of Monterey, Cali-

fornia, an authority on sea otters, and Dr. and Mrs. Donald T. Abbott of Stanford University's Hopkins Marine Station at Pacific Grove contributed to the completion of the manuscript.

Robert T. Orr
Associate Director, California
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INTRODUCTION

The following study is a presentation of the musculature of the hind limb of the sea otter. Having published the muscular anatomy of the forelimb of the sea otter (Howard, 1973) it seems only logical that a similar study of the hind limb be undertaken.

The hind limb is grossly different from the forelimb both anatomically and functionally, being used almost exclusively for swimming and showing a high degree of specialization for this purpose. The limb is relatively short and heavily muscled. The hip and knee are semi-flexed and for the most part the foot is in the plantar flexed position. Detailed studies of the use of the hind limbs in swimming have been made by Tarasoff *et al.* (1972).

The hind foot is large compared to the front foot, its length equaling that of the lower leg. Both metacarpals and phalanges are elongated and a generous skin web exists between the digits. The 5th digit is the largest and the longest, and the 1st digit the smallest. The foot becomes twice as wide when the toes are spread. In the hind foot the elongated digits and generous webbing make for individual digit mobility far in excess of that possible in the front foot.

DESCRIPTION OF THE LOWER EXTREMITY OF THE SEA OTTER

Like the upper extremity, the lower extremity is relatively short in comparison with body length and is heavily muscled in the upper and lower leg.

The foot is highly developed for aquatic propulsion and is completely covered with fur. The skin of the foot is soft and mobile with the exception of the terminal digital pads. Broad, soft webbing of skin is present between the toes extending in slightly scalloped fashion to the very tips of the digits. Unlike the forefoot or hand and in spite of the heavy fur cover, the individual digits are grossly identifiable on both volar and dorsal surfaces.

Even in the preserved specimen, the individual digital joints are highly mobile. Three phalanges are present in digits five, four, three, and two, with but two phalanges in the 'great toe' which in this case is the smallest digit. The proximal or metacarpal phalangeal joints hyperextend approximately 40° beyond the straight line. Flexion is to 110°. The middle toe joints or proximal interphalangeals extend to 55° beyond the straight line

and flex to 115° . The distal joints or distal interphalangeal joints extend to 45° above the straight line and flex to 65° . For digit one, only a single interphalangeal joint is present. This single interphalangeal joint extends to approximately 45° beyond the straight line and flexes to approximately 75° .

When spread, the distance between the tips of toes one and five is twice, or a little more than twice, the distance when the toes are together.

An arched and curved claw is present for each digit. Each is about equal in size, the one on digit four being perhaps slightly heavier. The distal pads cover the plantar aspect of the terminal phalanges covering approximately the distal one-third or one-fourth of the middle phalanx. A small pad also occurs at the base the 'great toe.'

Due to the extreme mobility of the small joints of the foot, when the metacarpal, phalangeal, and interphalangeal joints are flexed to their passive limits the tips of the toes actually touch the sole of the foot, curving around an ample area to permit actual grasp of objects (two or three fingers in a grip-like manner). Vandever (pers. commun.) has seen on numerous occasions food, a tool, and a pup held against the body but never grasped by the toes.

Also because of the interdigital webs, the individual digits themselves are more highly mobile and thus the pad of the fifth can touch the pads of the fourth and the third in the manner of apposition, and can touch the pads of the second and the first in the configuration of opposition.

Thus it would appear that the foot has the potential of being rather highly prehensile in contrast to the hand, yet in spite of this the foot serves mainly for locomotion in water and to a degree for grooming. The foot appears to be more suitable than the hand as an organ for grasping food and the hand is superior to the foot as an organ for locomotion on land.

Thus the extremities present a kind of a paradox for a mammal returning to the sea. The hind legs and feet have made ready adaption for aquatic locomotion, the forefoot or hand seeming to persist in a form for ambulation on land. An amusing conclusion would be that the animal entered the sea backwards! Perhaps the forelimbs are becoming functionally obsolete as organs of locomotion in swimming.

An outstanding feature is the development of the outer side of the foot, with the fifth digit, the shortest in land mammals, becoming more massive and longer than all of the remaining digits. In seals the fifth digit has also become massive and long, but not noticeably more massive or longer than the great toe. When sea otters are swimming on their backs, this development of their fifth digit gives maximum skulling surface and the largest excursion of motion. In underwater swimming, accomplished by undulations of the body in the AP diameter, the trailing feet can take on the general configuration of the flukes of a whale.

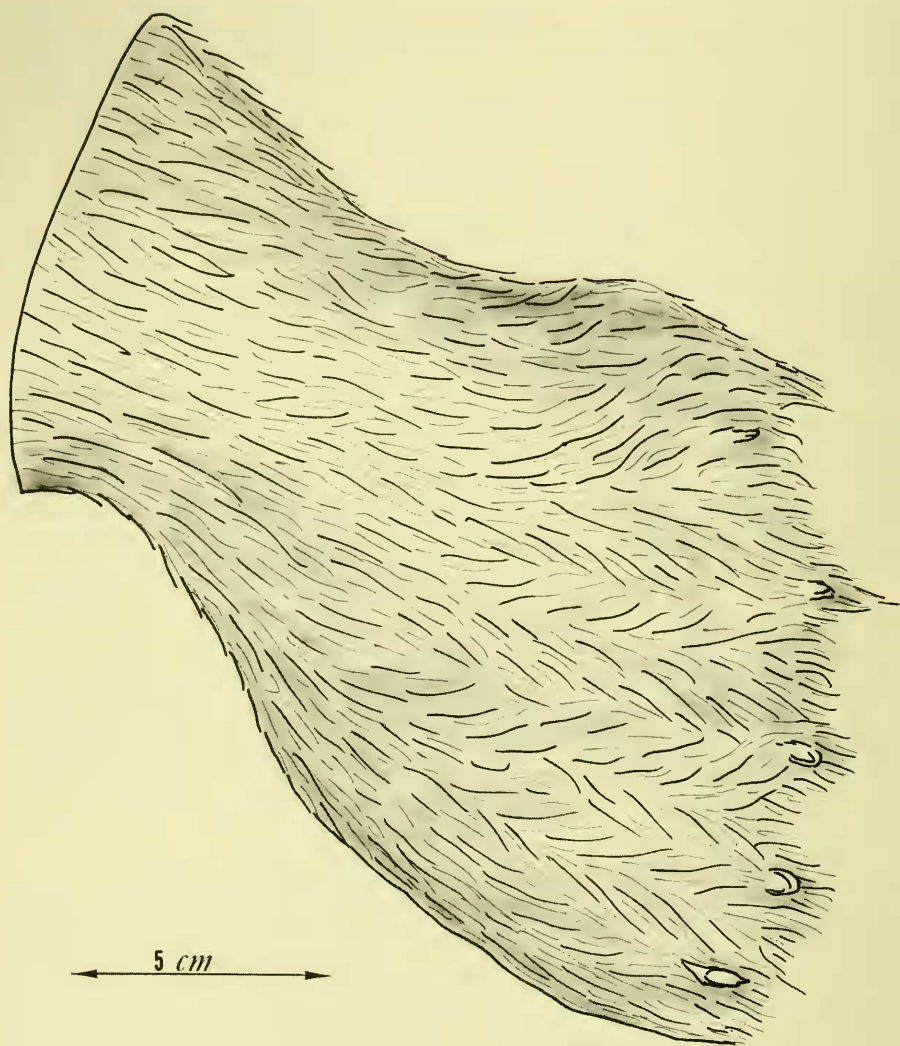


FIGURE 1. Dorsal view of right hind foot. Note elongation of the digits on the lateral side of the foot so that the fifth digit becomes the longest. Also note the tendency of the digits to angulate slightly medially.

The claws terminate the distal phalanges of each digit. Unlike the forefoot, the terminal phalanges are not hyperextended but lie in line with the proximal and middle phalanges.

Skin webbing between the digits is extensive and the entire dorsal surface of the foot is covered with hair.

MUSCLES OF THE HINDLIMB OF THE SEA OTTER
ALPHABETICAL LISTING

Muscle	No.	Muscle	No.
Abductor digiti quinti	40	Interossei (interosseus)	46
Abductor hallucis	43	Lumbricales	48
Adductor digiti quinti	41	Obturator externus	21
Adductor femoris	5s = superficial	Obturator internus	23
	5d = deep	Opponens digiti quinti	42
Adductor hallucis	44	Panniculus carnosus	A
Adductor longus	5-A	Pectineus	6
Biceps femoris	12	Peroneus brevis	30
Caudofemoralis	11	Peroneus digiti quinti	29
Calcaneometatarsalis	39	Peroneus longus	28
Extensor digitorum brevis	47	Plantaris	31
Extensor digitorum longus	27	Popliteus	32
Extensor hallucis proprius (longus)	26	Presemimembranosus	17
Flexor digitorum brevis	37	Piriformis	19
Flexor digitorum longus	36	Quadratus plantae	38
Flexor hallucis longus	35	Rectus femoris	7
Gastrocnemius	24	Sartorius	1
Gemelli (gemellus)	20	Semimembranosus	4
Gluteus maximus	9	Semitendinosus	3
Gluteus medius	16	Tenuissimus	13
Gluteus minimus	18	Tibialis anterior	25
Gracilis	2	Tibialis posterior	34
Iliocapsularis (quadratus femoris)	22	Vastus medialis	14
Iliopsoas	8	Vastus lateralis	10

DESCRIPTIONS OF MUSCLES

A. Panniculus carnosus.

This voluntary muscle for moving the skin is well developed in the area of the hind limb of the sea otter. The skin and subcutaneous tissues are very mobile over the underlying deep fascia. The panniculus carnosus muscle is a broad thin layer of rather coarse longitudinal muscle fibers closely attached to the undersurface of the skin, so closely that rather meticulous sharp dissection is required to separate them.

ORIGIN. For the hind limb, this muscle layer is a continuation of that present in the trunk area. The fibers paralleling the middorsal line cover most of the lateral aspect of the hind limb and wrap about the knee to reach the medial surface of the limb to some degree in this area.

INSERTION. Insertion of this muscle is in the deep layers of the skin as far posteriorly as the skin web between the tail and the ankle.

ACTION. This muscle serves to voluntarily mobilize the skin over the hind limb from the trunk to the heel area.

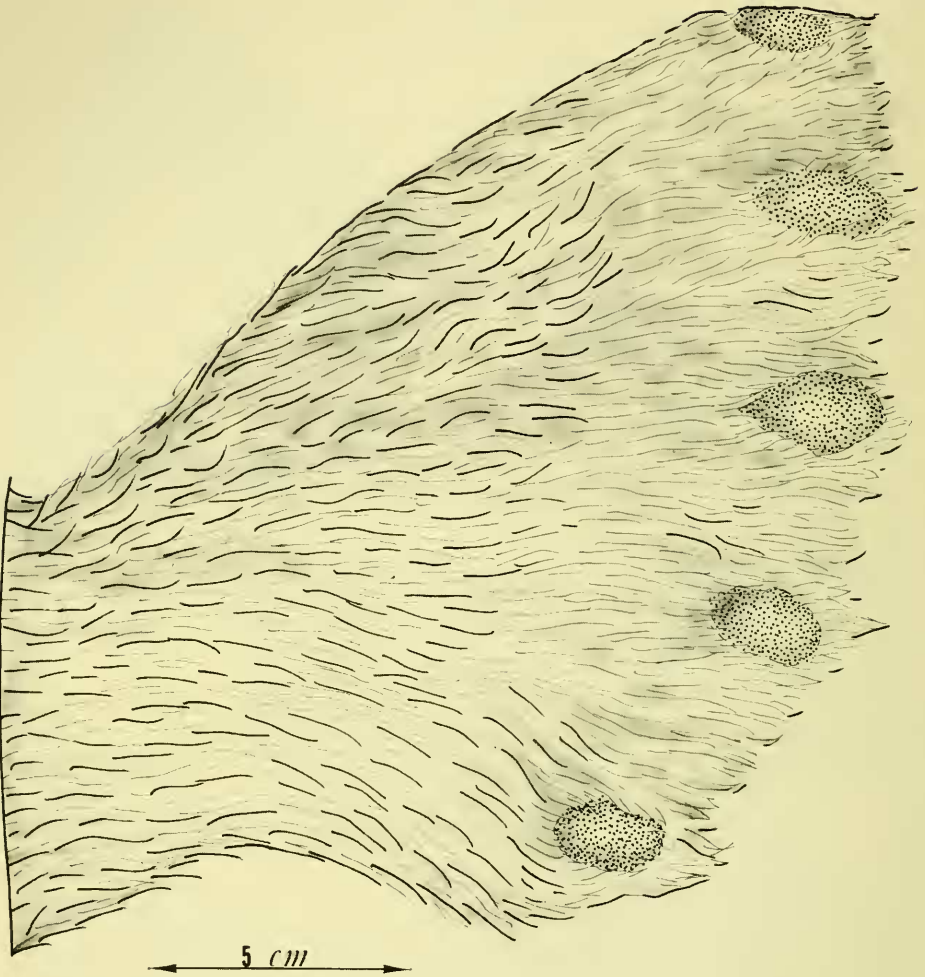


FIGURE 2. The plantar view of the right hind foot. Note the relatively small pads overlying the terminal phalanges of each digit. A smaller pad at the metatarsophalangeal joint of digit 1 is covered with hair and therefore is out of view. The pads have a rough texture similar to the pads of the forefoot. Hair coverage on the plantar surface of the foot is extensive.

1. *Sartorius*.

This muscle is fleshy, somewhat flat, and superficial in position, overlying the anterior aspect of the hind limb connecting the pelvis to the knee area.

ORIGIN. The muscle arises by fleshy and short tendinous fibers from the iliac crest. It is the most superficial muscle overlying in part the origins of

the glutei musculature. The muscle passes distally from its origin over the anterior thigh, narrowing somewhat and shifting slightly medial.

INSERTION. The insertion is along the full length of the patella tendon with some short tendinous fibers entering the medial side of the tibial tubercle.

ACTION. This muscle assists in extension of the knee through its patellar tendon attachment and also assists in flexion of the hip.

2. *Gracilis.*

This broad, flat, superficial muscle is on the medial aspect of the lower limb and connects the pelvis with the tibia.

ORIGIN. The muscular fibers of origin come from the full width of the pubis in the area of the symphysis. From its origin, the muscle maintains a constant width and courses like a muscular strap toward the upper tibia.

INSERTION. The insertion is by fleshy and short tendinous fibers into the tibial crest beginning at and extending distal to the tibial tubercle. The insertion overlies the insertion of the semitendinosus (3).

ACTION. This muscle serves to adduct the lower limb and assists in flexion of the knee and internal rotation of the extremity.

3. *Semitendinosus.*

This muscle is a flat, somewhat triangular superficial muscle joining the caudal area of the axial skeleton to the tibia. This muscle participates with the biceps femoris (12) to form a sort of muscular web between the caudal area and the knee.

ORIGIN. This muscle arises as fleshy and short tendinous fibers from the spinous processes and associated fascia of caudal vertebrae 1-7. The more superior area of origin overlies the origin of the caudofemoralis (11) at the caudal 1-2 level. The muscle now crosses toward the medial side of the tibia and while so doing underlies and gives off a group of muscle fibers to the biceps femoris (12).

INSERTION. The muscle narrows as it approaches the tibia and terminates as a short flat tendon which inserts on the crest of the tibia partly under the insertion of the gracilis (2).

ACTION. This muscle assists in flexion of the knee and internal rotation of the lower limb.

4. *Semimembranosus.*

This is a somewhat flat muscle connecting the pelvis with the upper tibia.

ORIGIN. Muscular fibers arise superficially along the ischial tuberosity overlying and almost in common with a portion of the superficial division of the adductor femoris (5). The muscle then extends obliquely toward the knee underlying the gracilis (2) and paralleling the adductor femoris (5).

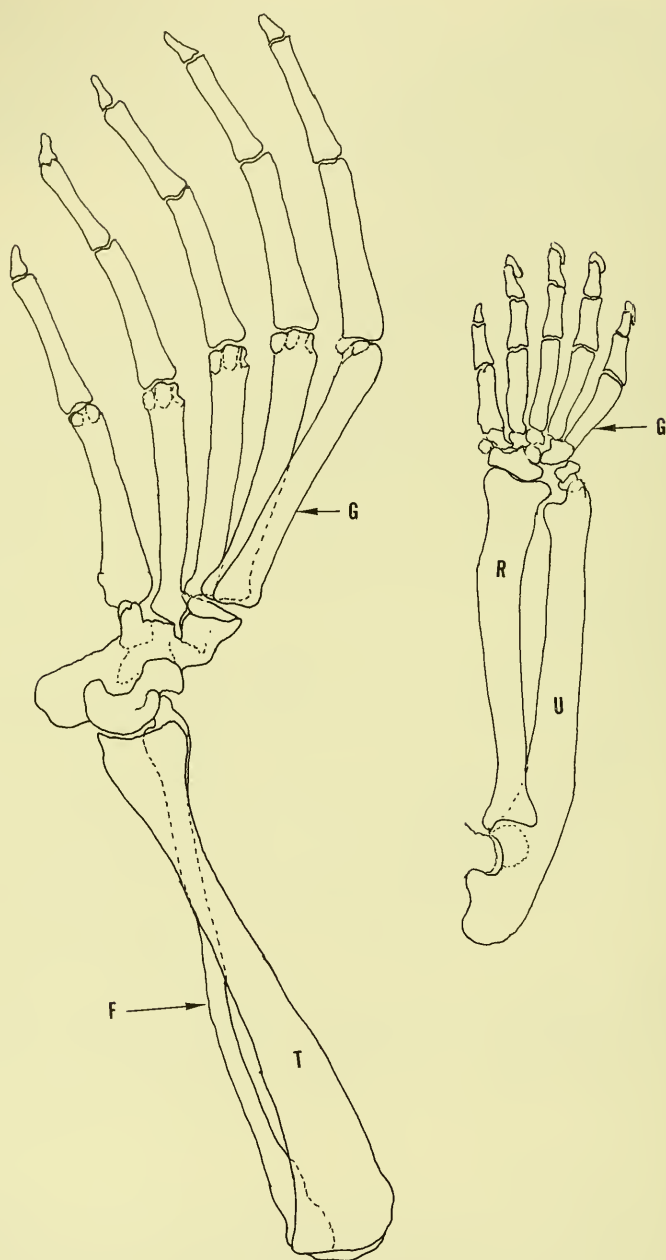


FIGURE 3. Tracing from an x-ray of the fore limb and hind limb of the same animal to show relationship of length of foot to length of limb and also relative length of digits compared one to the other. Key: F, fibula; G, digit 5; R, radius; T, tibia; U, ulna.

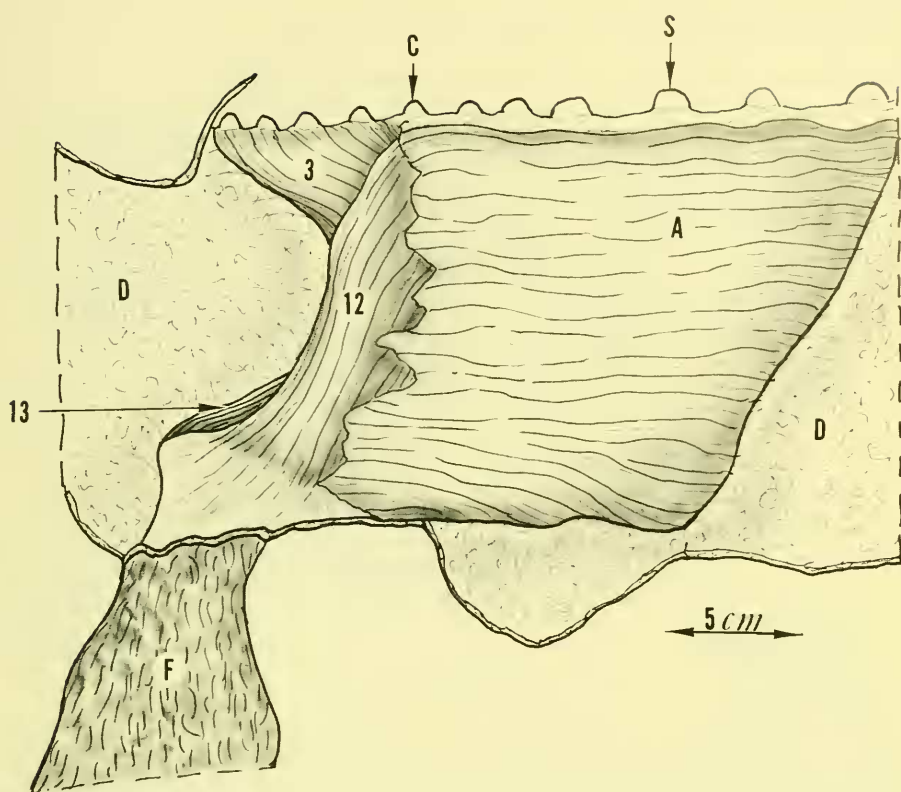


FIGURE 4. Lateral view of right lower extremity and caudal area. The skin has been carefully dissected from the panniculus carnosus muscle and reflected to show this most superficial muscle (A). The rather coarse parallel muscle fibers terminate in the deep layer of the skin in an irregular manner along the web-like fold of skin between the tail and the heel. Key: C, spinous process of the first caudal vertebra; D, reflected skin and subcutaneous tissue; F, foot; S, spinous process of the first sacral vertebra; A, panniculus carnosus; 3, semitendinosus; 12, biceps femoris; 13, tenuissimus.

INSERTION. Nearing its insertion, the muscle narrows to form a short flat tendon which passes under the medial collateral ligament of the knee and inserts on the tibia just medial to the tuberosity at the level of the junction of the insertion of the gracilis (2) and sartorius (1).

ACTION. This muscle serves as a flexor of the knee and an internal rotator of the lower limb.

5. Adductor femoris.

The adductor femoris is a large muscle joining the pelvis with the femur. It is divided into two: the superficial and deep portions.

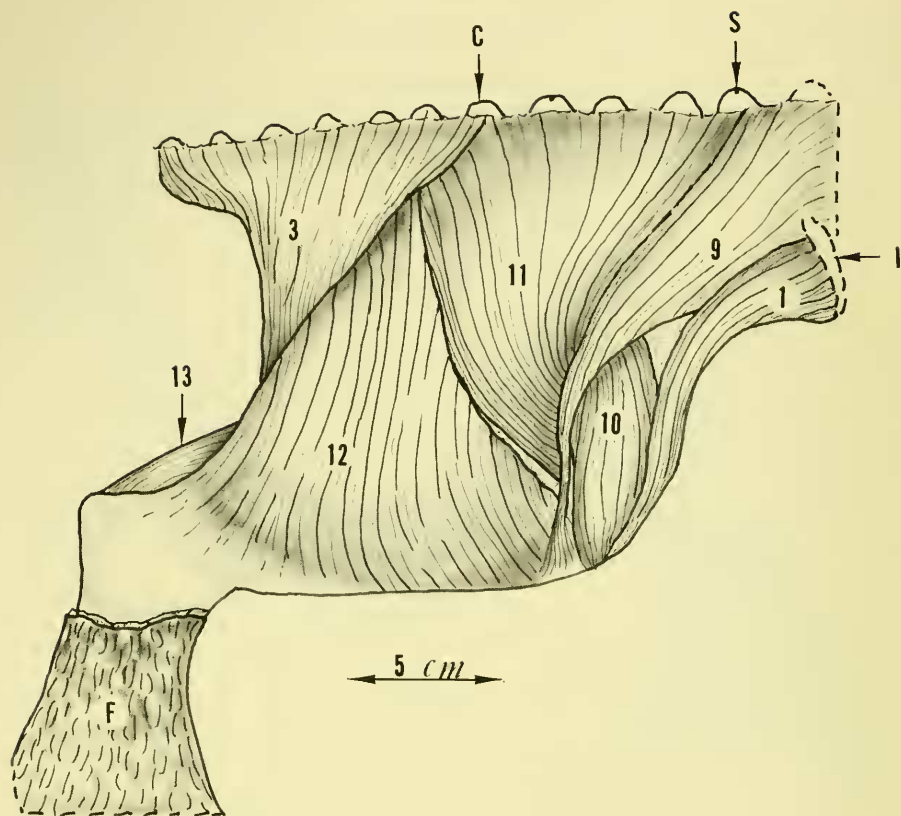


FIGURE 5. Lateral view of right lower extremity and hip area. The panniculus carnosus muscle (A) has been removed to show the disposition of the superficial musculature beneath. Key: C, spinous process of first caudal vertebra; F, foot; I, iliac crest; S, spinous process of first sacral vertebra; 1, sartorius; 3, semitendinosus; 9, gluteus maximus; 10, vastus lateralis; 11, caudofemoralis; 12, biceps femoris; 13, tenuissimus.

SUPERFICIAL PORTION.

ORIGIN. The superficial portion arises from the most distal area of the external surface of the pelvis adjacent to the origin of the semimembranosus and in close association with the deep portion of the adductor femoris. From the semitriangular area of origin the muscle broadens and flattens as it approaches the knee area where it underlies the broad sartorius muscle (1).

INSERTION. The insertion by muscular and short tendinous fibers is over a fairly broad area about the knee. The more distal fibers insert into the medial epicondyle area of the femur and the remainder insert into the deep fascia on the medial side of the knee joint.

ACTION. Adduction of the femur.

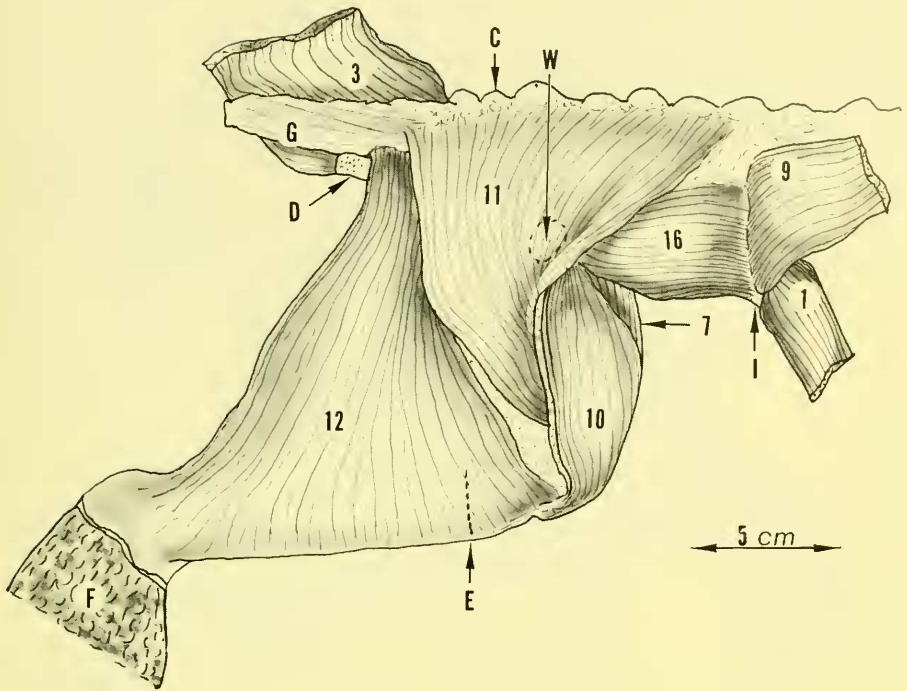


FIGURE 6. Lateral view of right lower extremity and hip area. The sartorius (1) and the gluteus maximus (9) have been reflected superiorly from their origins, and the semitendinosus (3) has been reflected dorsally. Origins of the biceps femoris (12) and the caudofemoralis (11) are more clearly visualized. Seen in the deeper layer of muscle are the gluteus medius (16) and the rectus femoris (7). Key: C, spinous process of the first caudal vertebra; D, ischial tuberosity; E, knee joint level; F, foot; G, caudal musculature; I, iliac crest; W, femur (greater trochanter); 1, sartorius (reflected); 3, semitendinosus (reflected); 7, rectus femoris; 9, gluteus maximus (reflected); 10, vastus lateralis; 11, caudofemoralis; 12, biceps femoris; 16, gluteus medius.

DEEP PORTION.

ORIGIN. The deep portion of this muscle arises from the external surface of the ischium and pubis immediately proximal to and almost in common with the superficial portion. The greater area of the crescent shaped origin is from the pubic bone, where it borders the gracilis muscle (2) origin medially and the origin of the adductor longus (5A) superiorly. From its origin, the muscle parallels the superficial portion as it passes toward the femur.

INSERTION. Distally, the muscle spreads fan-like to insert by tendinous fibers into the posteromedial aspect of the femur. The more distal portion underlies the insertion of the superficial portion of the adductor femoris in

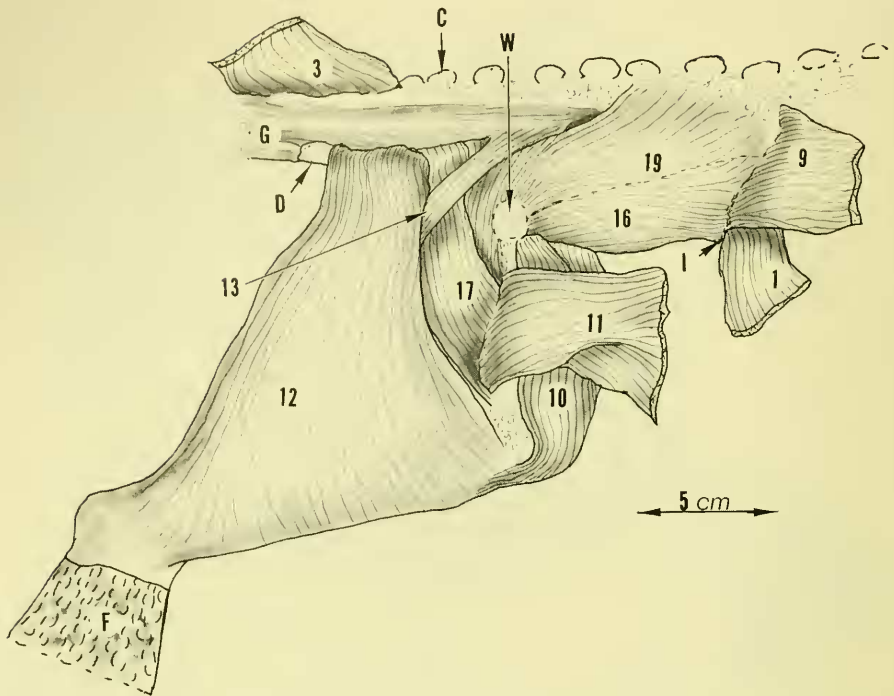


FIGURE 7. Lateral view of the right lower extremity and hip area, similar to figure 6 but with the caudofemoralis (11) detached at its origin and reflected anteriorly. The deeper muscles are thus exposed, and the area of origin of the biceps femoris (12) and gluteus medius (16) are clearly seen. Key: C, spinous process of first caudal vertebra; D, ischial tuberosity; F, foot; G, caudal musculature; I, iliac crest; W, femur (greater trochanter); 1, sartorius (reflected); 3, semitendinosus (reflected); 9, gluteus maximus (reflected); 10, vastus lateralis; 11, caudofemoralis (reflected); 12, biceps femoris; 13, tenuissimus; 16, gluteus medius; 17, presemimembranosus; 19, piriformis.

the area of the medial epicondyle of the femur. Insertion extends proximally along the medial ridge to the level of the lesser trochanter.

ACTION. The muscle is an adductor of the femur.

5A. Adductor longus.¹

This muscle is the most superior of the adductor group and is smaller than the others.

ORIGIN. The origin of this muscle is by short tendinous and muscular fibers from the external surface of the superior ramus of the pubis. At the symphysis the origin is adjacent to the gracilis muscle (2) and superiorly

¹ There is some indication in Dr. Howard's notes that he intended to renumber this muscle as '15.' Editor.

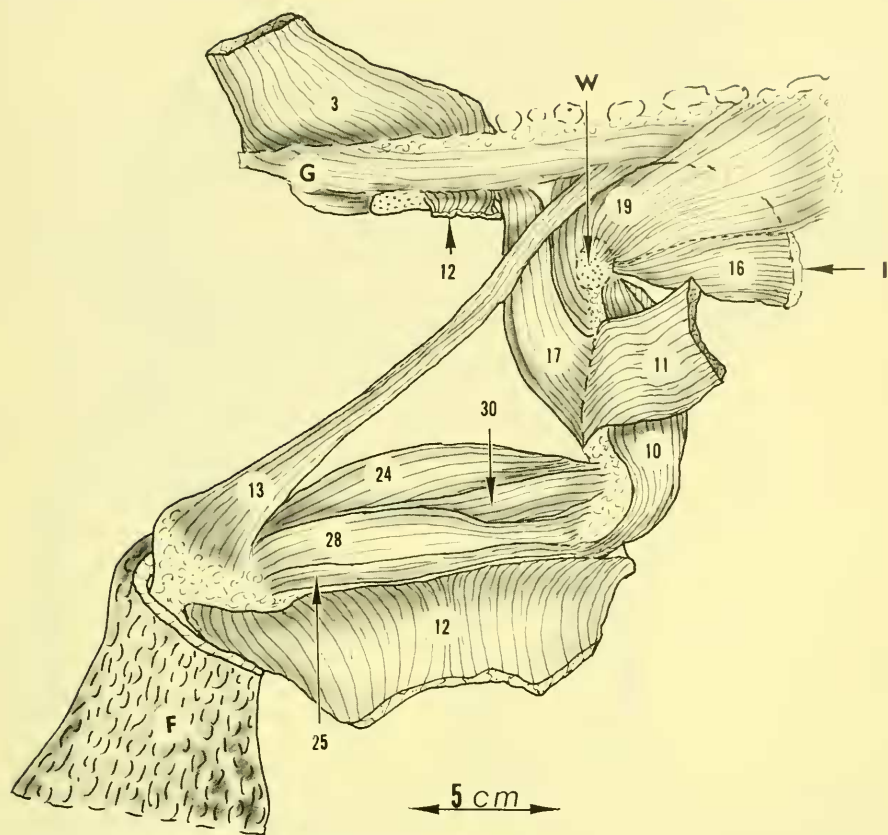


FIGURE 8. Lateral view of right lower extremity and hip area. The large biceps femoris (12) has been detached from its origin leaving a short stump and reflected anteriorly at its insertion. As a result, the musculature of the lower leg is exposed and the tenuissimus (13) and presemimembranosus (17) are seen from their origin to their insertion. Key: F, foot; G, caudal musculature; I, iliac crest; W, femur (greater trochanter); 3, semitendinosus; 10, vastus lateralis; 11, caudofemoralis (reflected); 12, biceps femoris (reflected from the tibia and also the stub from the pelvis); 13, tenuissimus; 16, gluteus medius; 17, presemimembranosus; 19, piriformis; 24, gastrocnemius; 25, tibialis anterior; 28, peroneus longus; 30, peroneus brevis.

the origin extends to that of the pectineus (6). On the pubis, the origin of the deep portion of the adductor femoris (5) is immediately adjacent distally.

INSERTION. This muscle parallels the other adductors to a long insertion the full length of the medial ridge of the femur adjacent and anterior to the deep portion of the adductor femoris (5) and just posterior to the pectineus (6), thus inserting between these two muscles.

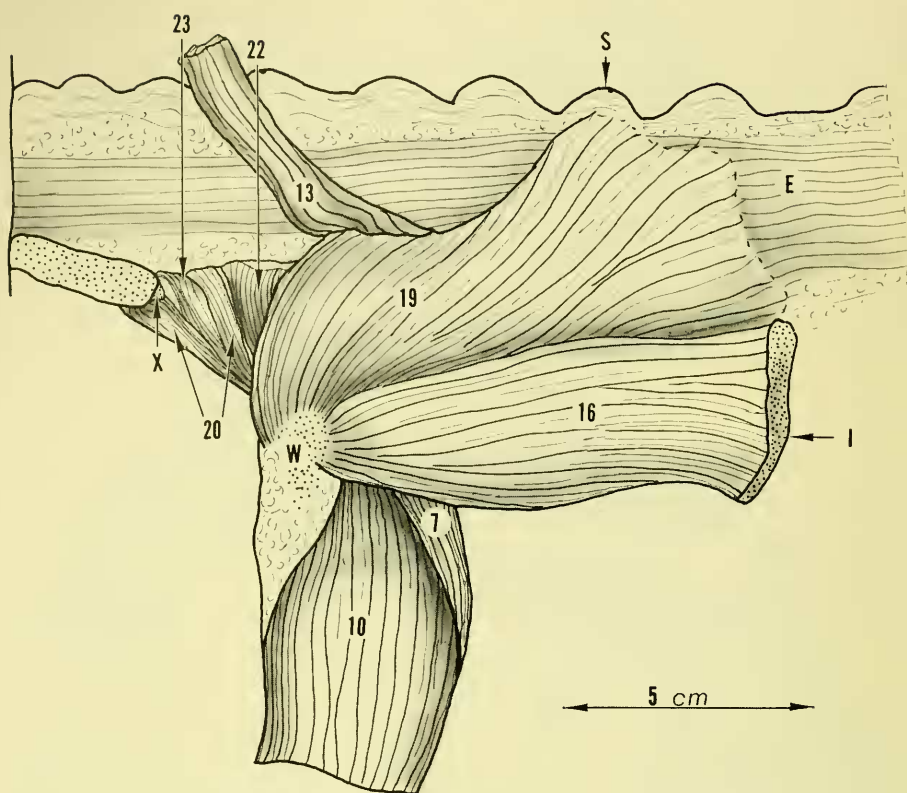


FIGURE 9. An enlarged dorsolateral view of the right hip area. Superficial muscles have been removed to disclose the deeper musculature about the hip joint and the relationship of these muscles to one another. Key: E, spinal musculature and fascia; I, iliac crest; S, spinous process of first sacral vertebra; W, femur (greater trochanter); X, ischial spine; 7, rectus femoris; 10, vastus lateralis; 13, tenuissimus (reflected); 16, gluteus medius; 19, piriformis; 20, gemelli; 22, iliocapsularis; 23, obturator internus.

ACTION. Adduction and internal rotation of the femur would result from contraction of this muscle.

6. Pectineus.

This is a smaller muscle, as far as total mass is concerned, but is clearly associated with the adductor group connecting the pelvis to the femur.

ORIGIN. The muscle arises in an elliptical configuration from the full width of the anterior surface of the pelvic bone directly opposite the acetabulum and just proximal to the adductor longus (5A).

INSERTION. From its origin, the muscle fans out paralleling the adductors

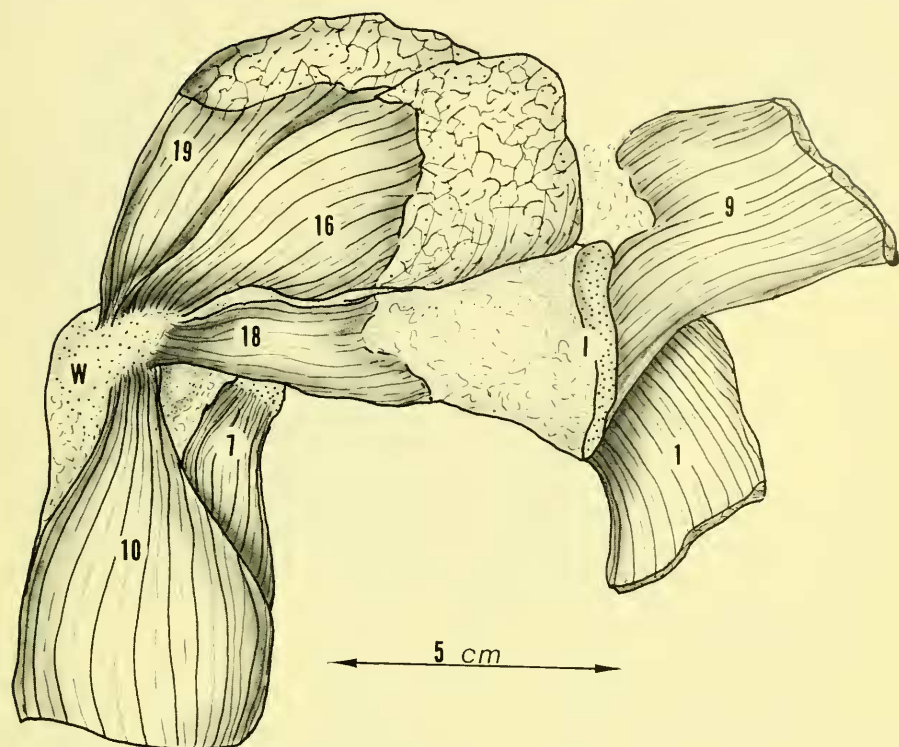


FIGURE 10. An enlarged and localized lateral view of the right hip area. The sartorius (1) and gluteus maximus (9) have been reflected from the iliac crest. The gluteus medius (16) has been peeled off the wing of the ilium and, with the piriformis (19), rolled upward to disclose the gluteus minimus (18). Also visualized are the origins of the rectus femoris (7) and vastus lateralis (10). Key: I, iliac crest and wing of ilium; W, femur (greater trochanter); 1, sartorius (reflected); 7, rectus femoris; 9, gluteus maximus (reflected); 10, vastus lateralis; 16, gluteus medius (reflected); 18, gluteus minimus; 19, piriformis (reflected).

to insert along the full length of the anterior ridge of the femur just anterior to the adductor longus (5A).

ACTION. This muscle would give adduction and internal rotation to the femur.

7. Rectus femoris.

This muscle is round in cross-section proximally and laterally compressed distally. It is a large fusiform muscle overlying the anterior surface of the femur joining the pelvis to the tibia.

ORIGIN. A short strong tendon of origin arises from the pelvic bone

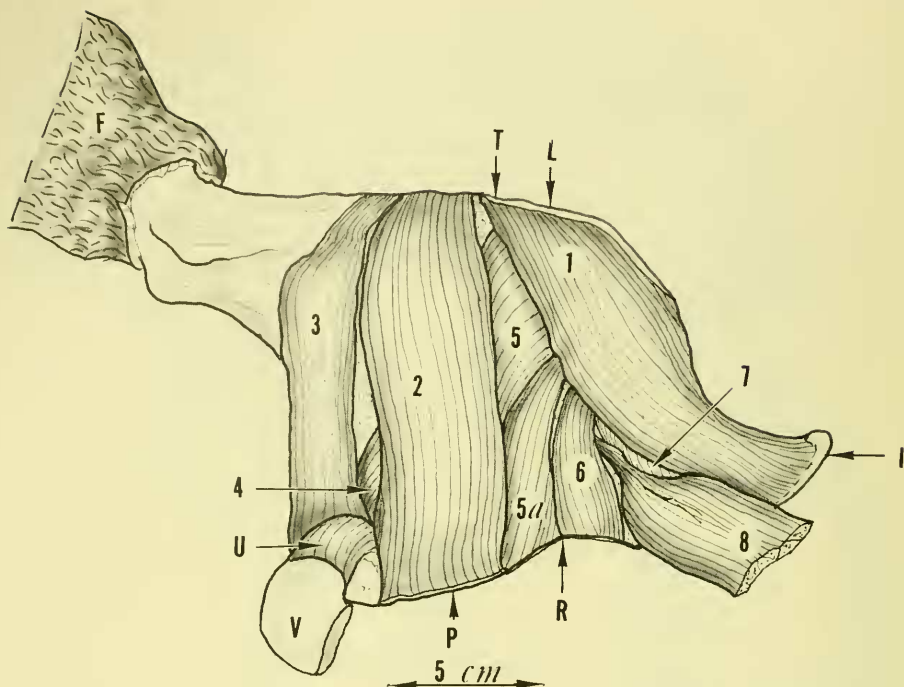


FIGURE 11. Medial view of the right lower extremity. The limb has been abducted approximately 90° so that the pelvic area presents an anterior view. With the skin and subcutaneous tissues removed, the superficial musculature is shown. Key: F, foot; I, iliac crest; L, patellar ligament; P, symphysis pubis; R, pelvic rim; T, tibial tuberosity; U, perineal muscles; V, penis; 1, sartorius; 2, gracilis; 3, semitendinosus; 4, semimembranosus; 5, adductor femoris; 5A, adductor longus; 6, pectineus; 7, rectus femoris; 8, iliopsoas.

(ilium) just above the acetabulum in the anterolateral area. At the site of origin, the bone has two shallow crater-like depressions joined by a slight ridge of bone. From its tendinous origin the muscle enlarges in a spindle-like form passing distally along the anterior femur overlying and being bordered by the vastus medialis (14) and vastus lateralis (10).

INSERTION. Tendinous fibers of insertion begin developing in the distal one-third of the muscle, particularly on the medial side. A strong tendon is present at the insertion into the proximal end of the patella. Laterally, the tendon of insertion of the vastus lateralis (10) joins in to make a common insertion. Medially, the vastus medialis (14) with fleshy fibers underlies the rectus femoris tendon but inserts into the patella to the medial side of the rectus femoris tendon. The strong patellar tendon then continues the insertion of all three muscles to the tibial tubercle.

ACTION. Strong extension of the knee.

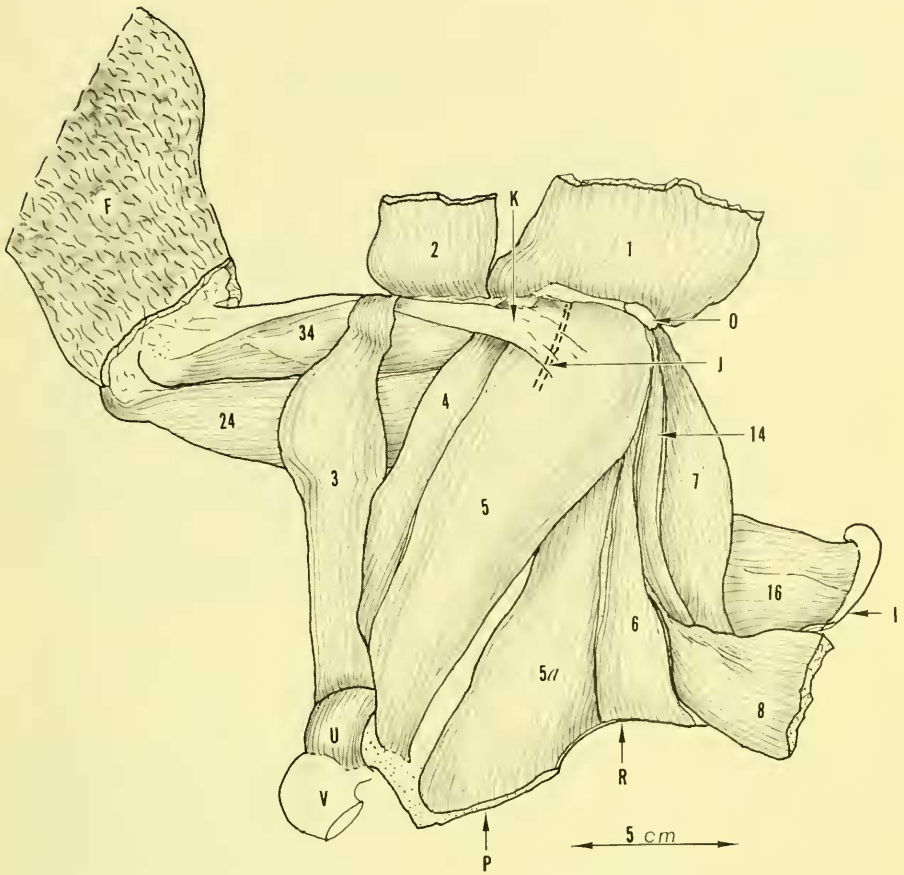


FIGURE 12. Medial view of abducted right lower leg. The sartorius (1) and the gracilis (2) have been reflected at their insertions to show relationship of the underlying deeper musculature. The medial collateral ligament of the knee takes its origin from the femur in the area of insertion of the superficial portion of the adductor femoris (5). Key: F, foot; J, tibial plateau; K, medial collateral ligament of the knee; O, patella; P, symphysis pubis; R, pelvic rim; U, perineal muscle; V, penis; 1, sartorius (reflected); 2, gracilis (reflected); 3, semitendinosus; 4, semimembranosus; 5, adductor femoris; 5A, adductor longus; 6, pectineus; 7, rectus femoris; 8, iliopsoas; 14, vastus medialis; 16, gluteus medius; 24, gastrocnemius; 34, tibialis posterior.

8. Iliopsoas.

This is a large heavy muscle connecting the lumbar spine and ilium with the femur.

ORIGIN. Superior portion of this large muscle arises from the volar surfaces of the transverse processes of the last three lumbar vertebrae and adjacent fascia. As the muscle forms and passes caudally into the pelvis, an additional

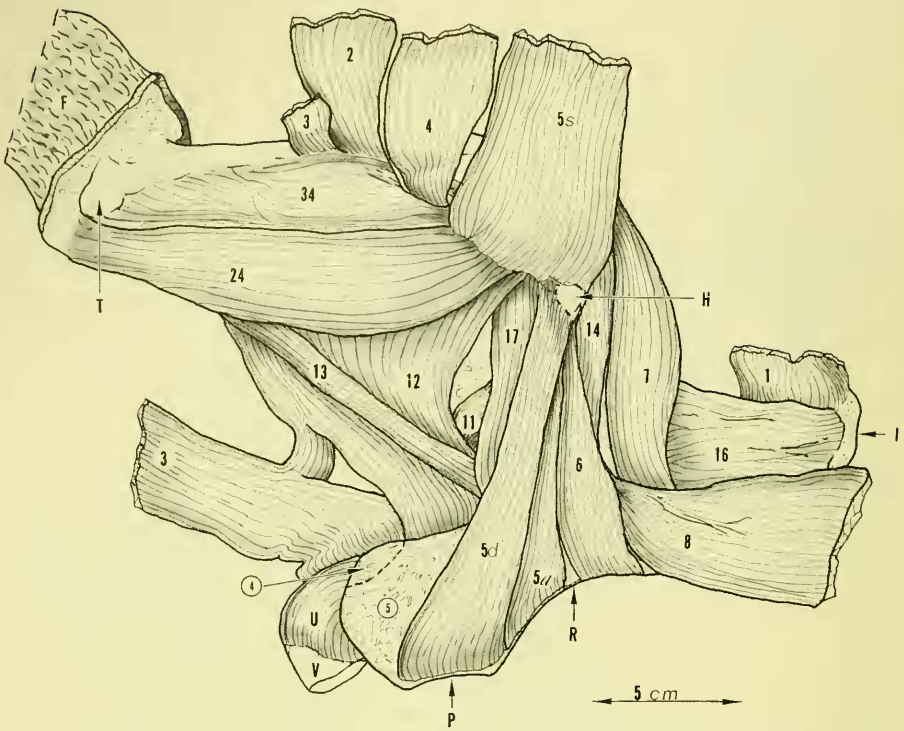


FIGURE 13. Medial view of abducted right lower extremity, similar to figure 12. The semimembranosus (4) and the superficial portion of the adductor femoris (5) have now been removed at their origin from the pubis and reflected at their insertions. Further detail of the adductor muscles is made visible, and other deep muscles shown in relationship to one another. Note the contribution of muscle fibers from the semitendinosus (3) to the biceps femoris (12). That portion of the sartorius (1) which arises from the iliac crest is shown reflected at that site. Key: F, foot; H, femur (medial epicondyle); P, symphysis pubis; R, pelvic rim; T, tibia (medial malleolus); U, perineal muscles; V, penis; 1, sartorius (reflected); 2, gracilis (reflected); 3, semitendinosus, origin and reflected muscle; 4, semimembranosus, origin and reflected muscle; 5, adductor femoris (origin of superficial portion); 5S, adductor femoris (superficial portion reflected); 5D, adductor femoris (deep portion); 5A, adductor longus; 6, pectineus; 7, rectus femoris; 8, iliopsoas; 11, caudo-femoralis; 12, biceps femoris; 13, tenuissimus; 14, vastus medialis; 16, gluteus medius; 17, presemimembranosus; 24, gastrocnemius; 34, tibialis posterior.

area of origin develops from the anterior surface of the ilium immediately adjacent to the sacroiliac joint.

INSERTION. The muscle becomes elliptical in transverse section and tapers into a heavy tendon which dips deeply along the side of the vastus medialis (14) to insert on the medial side of the lesser trochanter of the femur.

ACTION. Flexion and external rotation of the femur.

9. *Gluteus maximus*.

This is a flat triangular muscle lying over the extensor surface of the hip area connecting the pelvis with the femur and lateral fascia of the tibia.

ORIGIN. This muscle arises as a broad thin tendon from the outer side of the iliac crest. The origin is more or less fused with the tendon of origin of the *gluteus medius* (16). The anterior one-half of the origin underlies the origin of the muscle *sartorius* (1). The posterior one-half arises from the lumbar fascia overlying the spinal musculature in the area of the last lumbar vertebra. The muscle is superficial in position and from its origin triangulates toward the greater trochanter of the femur.

INSERTION. Near the upper femur, a short flat tendon develops from the greater portion of the muscle and inserts into the distal end of the greater trochanter, more or less in common with the proximal end of the *caudofemoralis* (11) insertion. Some of the more lateral fibers remain superficial and appear to insert into the deep fascia on the lateral aspect of the hip with continuation toward the knee. This portion may represent a *tensor fascia lata* muscle, although such a muscle is not specifically present in the sea otter.

10. *Vastus lateralis*.

This is the larger of the two vasti muscles which join the femur with the tibia through the patella and patella ligament.

ORIGIN. Fleшы fibers take origin from the proximal and lateral one-half of the femur. The origin begins on the anterior surface of the greater trochanter adjacent to the insertion of the *gluteus minimus* (18) and *medius* (16). The muscle then passes distally toward the knee joint where it joins with the *rectus femoris* (7).

INSERTION. The more lateral muscle fibers continue along the patella laterally and insert distal to but in the same plane as the tendon of the *rectus femoris* (7). The more medial fibers, which join in part with the *rectus femoris* (7), also form a strong short flat tendon which inserts into the lateral one-half of the proximal pole of the patella just under the *rectus femoris* (7) tendon.

ACTION. Extension of the knee through the patella and patella tendon.

11. *Caudofemoralis*.

This heavy superficial triangular muscle on the lateral aspect of the hip area connects the spine to the femur.

ORIGIN. The muscle arises from the spinous processes and deep fascia over the spinal muscles from the level of the last lumbar vertebra, the sacrum, and the first two caudal vertebrae. Inferiorly, the origin overlies two-thirds of the origin of the *biceps femoris* (12) and also the origin of the *tenuissimus* (13). Superiorly, the origin borders out of the *gluteus maximus* (9).

INSERTION. From its origin, the muscle triangulates somewhat and, passing over the greater trochanter, spreads to its insertion along the lateral femoral ridge of the inferior border of the greater trochanter to the upper border of the lateral femoral condyle.

ACTION. Abduction and external rotation of the femur.

12. **Biceps femoris.**

This is a very heavy and strong triangular muscle appearing superficially as the most prominent muscle on the lateral aspect of the lower limb. The muscle connects the pelvis to the tibia.

ORIGIN. The origin is by muscular tendinous fibers arising from a double bony exostosis-like protuberance along the posterior margin of the ischium just above the ischial tuberosity.

INSERTION. From its origin, the muscle spreads out fan-like to encompass the full length of the lower leg. Terminally, a thin flat tendon forms which inserts along the full length of the tibial crest laterally. Proximally, the insertion begins on the midlateral area of the tibia just below the joint surface. Distally, the tendinous fibers spread out into the deep fascia covering the entire lateral aspect of the ankle.

ACTION. This muscle acts as a flexor of the knee and external rotator of the lower limb.

13. **Tenuissimus.**

This is a long, uniformly thin and flat strap-type muscle bridging the sacrum to the ankle.

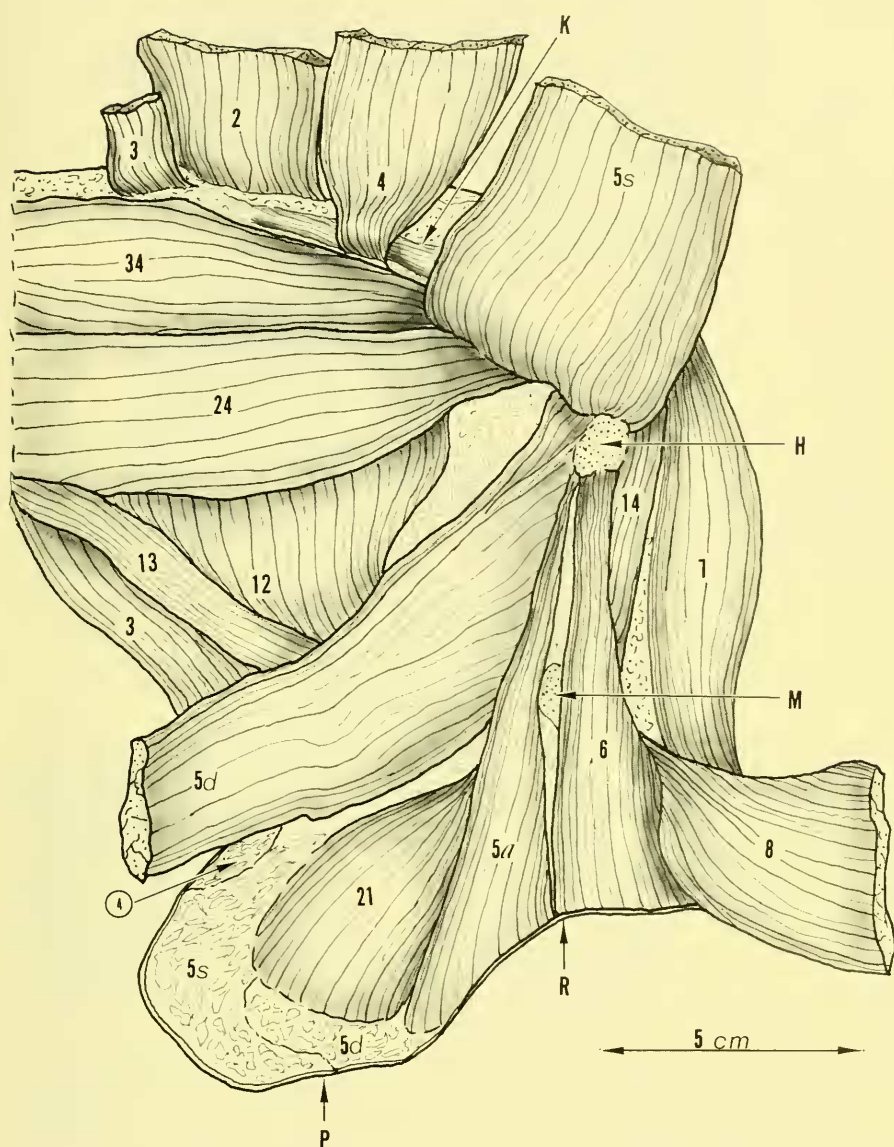
ORIGIN. This muscle arises as mostly muscular fibers from the transverse process of the third sacral vertebra and adjacent spinal muscle fascia. From here, the muscle courses diagonally toward the ankle, overlying the presemimembranosus (17) and underlying the caudofemoralis (11) and the biceps femoris (12).

INSERTION. At the ankle, the muscle inserts into a fascia-like structure on the lateral aspect which has attachments to the lateral malleolus and to the calcaneus.

ACTION. Action of this muscle would be to flex the knee and to plantar flex the ankle.

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FIGURE 14. Medial view of abducted right lower extremity, similar to figure 13, but in addition to the other reflected muscles, the deep portion of the adductor femoris (5D) has been removed from its origin and reflected distally. The relationship between the adductor longus (5A) and the pectineus (6) is now seen, and also the origin of the obturator



externus (21) is made visible. Key: H, femur (medial epicondyle); K, medial collateral ligament of knee; M, femur (lesser trochanter); P, symphysis pubis; R, pelvis rim; 2, gracilis (reflected); 3, semitendinosus (reflected); 4, semimembranosus (origin and reflected muscle); 5A, adductor longus; 5S, adductor femoris (superficial portion, origin and reflected muscle); 5D, adductor femoris (deep portion, origin and reflected muscle); 6, pectineus; 7, rectus femoris; 8, iliopsoas; 12, biceps femoris; 13, tenuissimus; 14, vastus medialis; 21, obturator externus; 24, gastrocnemius; 34, tibialis posterior.

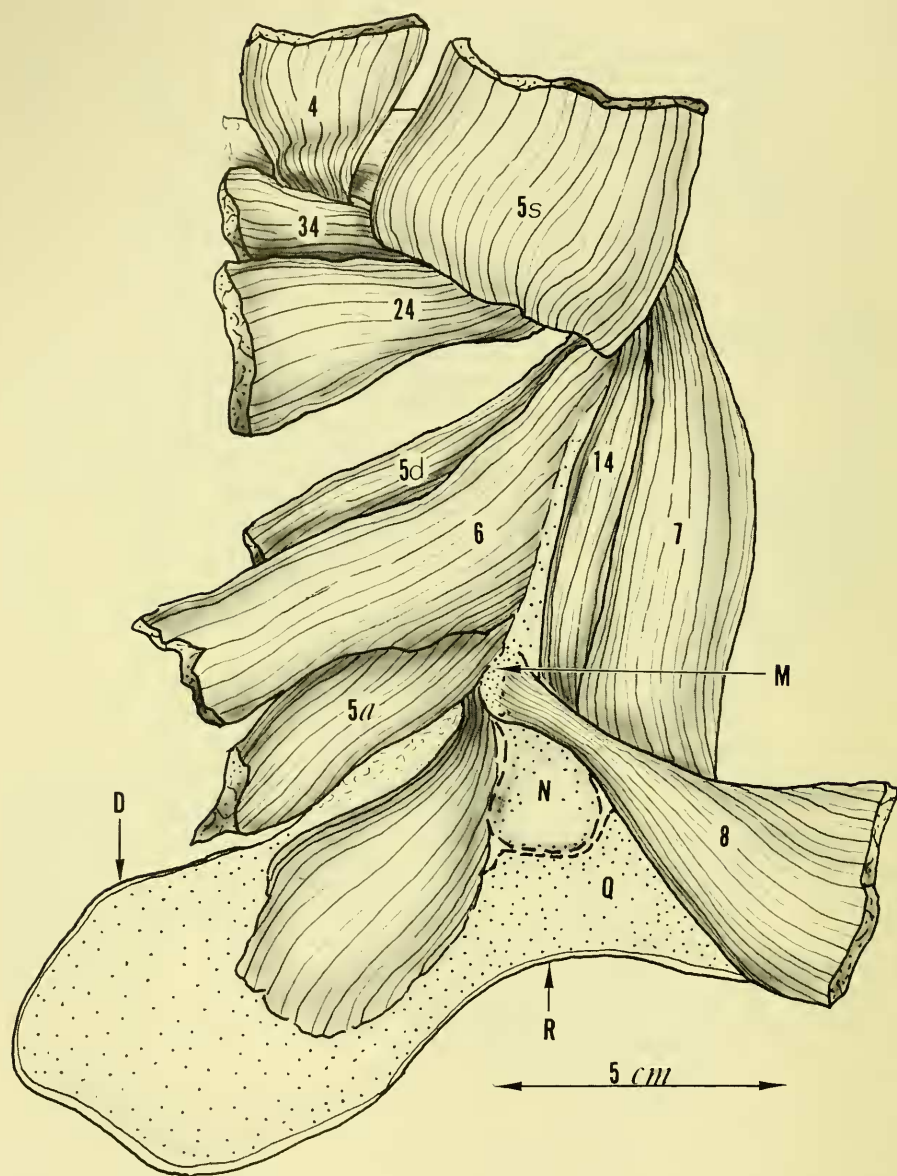


FIGURE 15. Medial view of abducted right lower extremity, similar to figures 13 and 14, but in addition the adductor longus (5A) and the pectineus (6) have been detached from their origins on the pelvis and reflected distally. By so doing, the head of the femur and the hip joint are exposed. Also, the insertion of the iliopsoas (8) can be seen as well as the relationship of the adjacent muscle. Key: D, ischial tuberosity; M, femur (lesser tuberosity); N, head of femur; Q, pelvis; R, pelvic rim; 4, semimembranosus; 5A, adductor

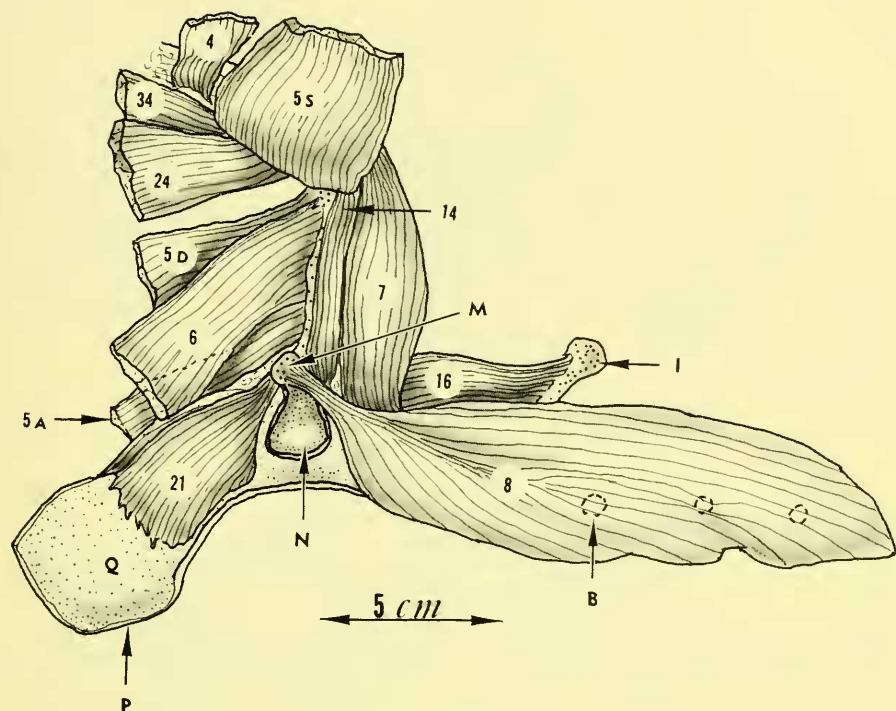


FIGURE 16. Medial view of abducted right lower extremity and ventral view of pelvis. The origin and insertion of the iliopsoas (8) muscle is shown. All of the deep muscles can be identified. Key: B, transverse process, last lumbar vertebra; I, iliac crest; M, femur (lesser trochanter); N, head of femur; P, symphysis pubis; Q, pelvis; 4, semimembranosus (reflected); 5A, adductor longus (reflected); 5S, adductor femoris (superficial portion, reflected); 5D, adductor femoris (deep portion, reflected); 6, pectineus (reflected); 7, rectus femoris; 8, iliopsoas; 14, vastus medialis; 16, gluteus medius; 21, obturator externus; 24, gastrocnemius; 34, tibialis posterior.

14. Vastus medialis.

This smaller of the two vasti muscles joins the femur to the tibia as a component of the extensor mechanism of the knee.

ORIGIN. Fleishy fibers arise from the medial one-half of the anterior surface of the femur. Proximally, the origin tapers to a point on the base of

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longus (reflected); 5S, adductor femoris (superficial portion, reflected); 5D, adductor femoris (deep portion, reflected); 6, pectineus (reflected); 7, rectus femoris; 8, iliopsoas; 14, vastus medialis; 24, gastrocnemius; 34, tibialis posterior.

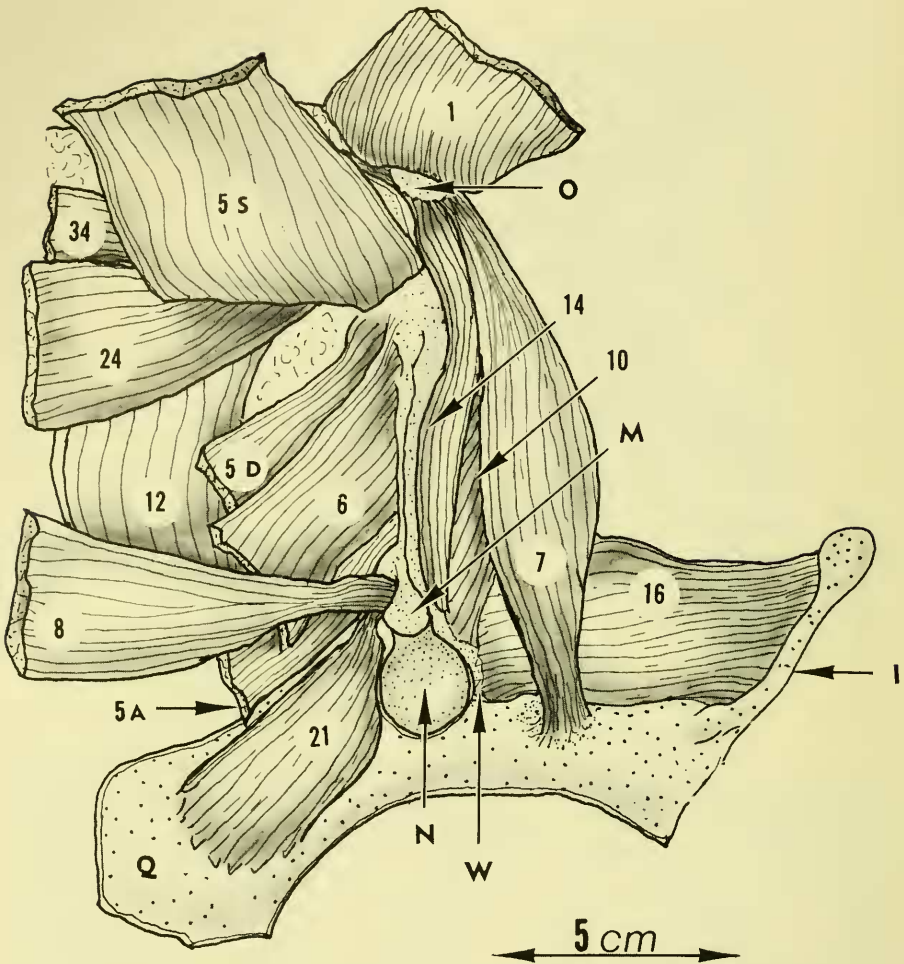


FIGURE 17. Medial view of abducted right lower extremity, similar to figure 16. The iliopsoas (8) has been detached from its origin on the lumbar vertebra and ilium and reflected posteriorly. Doing so uncovers the origin of the rectus femoris (7) and, with the rectus femoris displaced anteriorly a bit, the proximal origin of the vastus medialis (14) and vastus lateralis (10) can be seen. Also, the gluteus medius (16) can be seen going toward its insertion on the greater trochanter. Key: I, iliac crest; M, femur (lesser trochanter); N, head of femur; O, patella; Q, pelvis; W, femur (greater trochanter); 1, sartorius (reflected); 5A, adductor longus (reflected); 5S, adductor femoris (superficial portion, reflected); 5D, adductor femoris (deep portion, reflected); 6, pectineus (reflected); 7, rectus femoris (displaced); 8, iliopsoas (reflected); 10, vastus lateralis; 12, biceps femoris; 14, vastus medialis; 16, gluteus medius; 21, obturator externus; 24, gastrocnemius; 34, tibialis posterior.

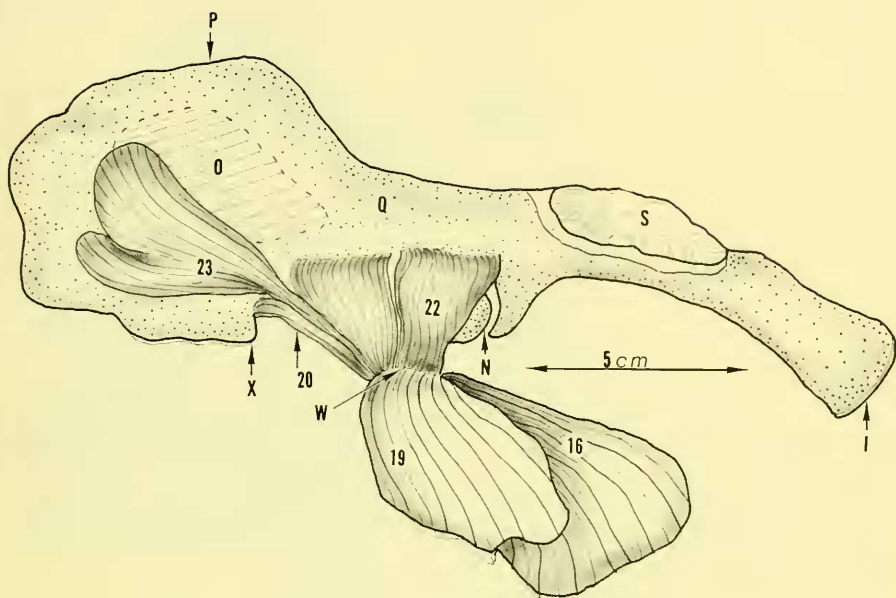


FIGURE 18. Medial view of right pelvis after disarticulation through the sacroiliac joint. The femur is viewed end-on from its proximal end, and the hip joint is visible. The gluteus medius (16) and piriformis (19) are reflected outward, and the origins and insertions of the short hip muscles can be seen. Key: I, iliac crest; N, head of femur; O, obturator foramen; P, symphysis pubis; Q, pelvis; S, sacroiliac joint; W, femur (greater trochanter); X, ischial spine; 16, gluteus medius; 19, piriformis; 20, gemelli; 22, iliocapsularis; 23, obturator internus.

the neck of the femur. Distally, the origin extends to just proximal to the articular surface, at which point it underlies the rectus femoris (7).

INSERTION. A short tendon forms distally and inserts into the medial one-half of the proximal end of the patella. This tendon partially underlies that of the vastus lateralis (10), which in turn underlies in part the rectus femoris (7) tendon.

ACTION. The action of this muscle is to extend the knee through the patella and its patellar tendon.

15. There is some indication in Dr. Howard's notes that muscle 5A—the adductor longus—should be numbered '15.' Editor.

16. **Gluteus medius.**

This large pyramidal-shaped muscle of coarse fibers connects the wing of the ilium to the greater trochanter of the femur.

ORIGIN. The muscle arises as fleshy fibers from most of the lateral surface

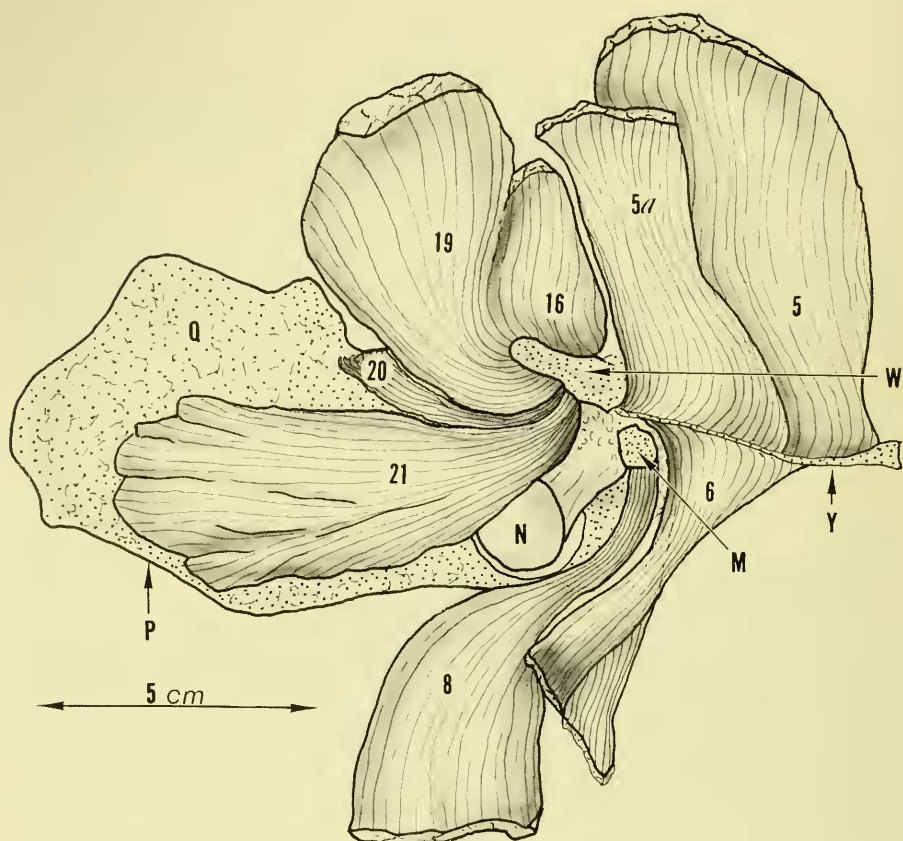
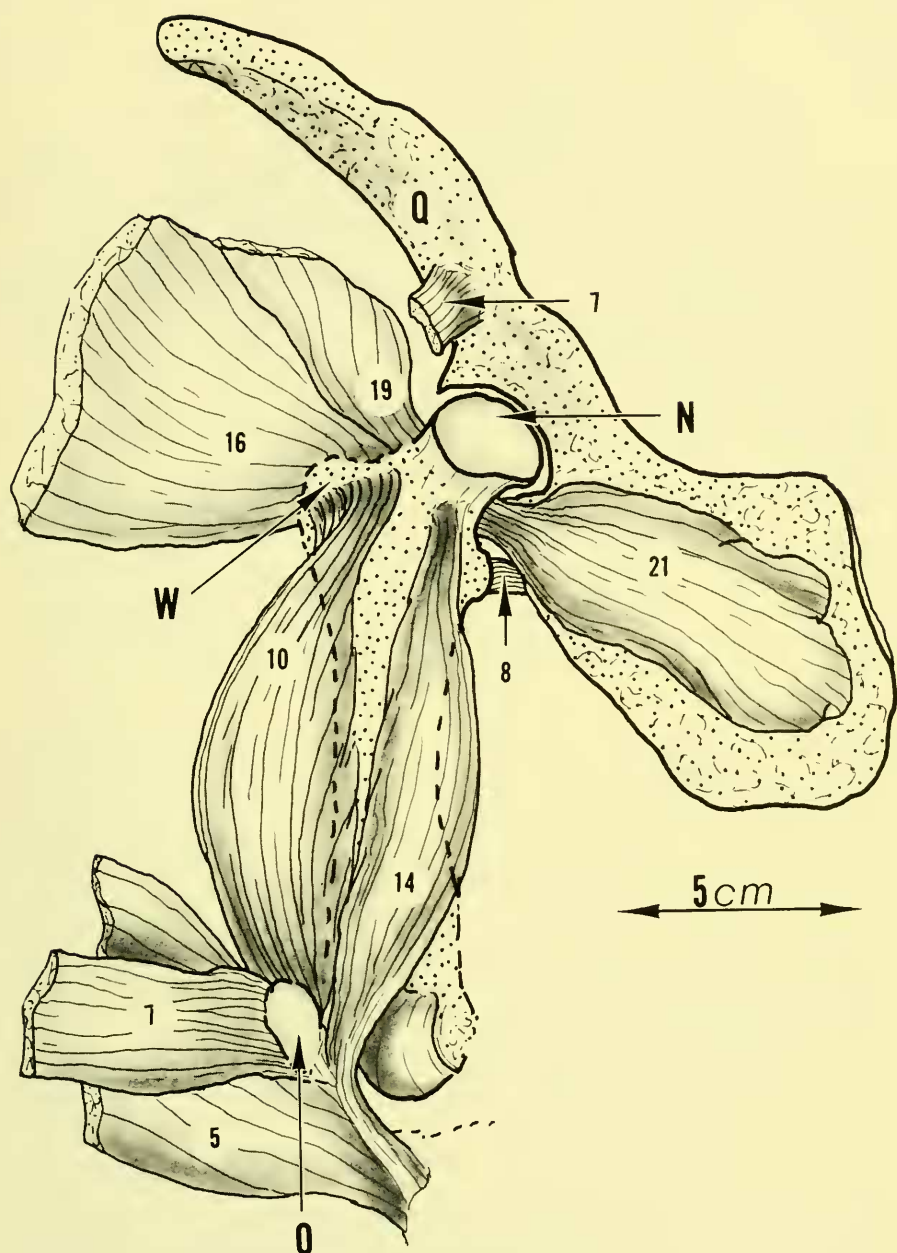


FIGURE 19. Lateral view of right pelvis with hip flexed and internally rotated so that the femur presents a posterior view showing both greater and lesser trochanters. Visible also are the head and neck of the femur and the hip joint. The obturator externus (21) is seen throughout its course. The other muscles have been reflected to disclose their insertions. Key: M, femur (lesser trochanter); N, head of femur; P, symphysis pubis; Q, pelvis; W, femur (greater trochanter); Y, femur (posterior ridge); 5, adductor femoris; 5A, adductor longus; 6, pectineus; 8, iliopsoas; 16, gluteus medius; 19, piriformis; 20, gemelli; 21, obturator externus.

of the wing of the ilium from the crest area to the lower border of the sacroiliac joint dorsally. The origin is practically inseparable from that of the gluteus minimus (18), which is immediately anterior and inferior on the iliac wing surface. Posteriorly, the muscle is practically inseparable from

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FIGURE 20. Anterior view of right femur and pelvis. The hip joint is exposed. The distal end of the femur is seen. The patella has been reflected laterally between the vastus



medialis (14) and the vastus lateralis (10), thus exposing its articular surface. Key: N, head of femur; O, patella; Q, pelvis; W, femur (greater trochanter); 5, adductor femoris; 7, rectus femoris; 8, iliopsoas; 10, vastus lateralis; 14, vastus medialis; 16, gluteus medius; 19, piriformis; 21, obturator externus.

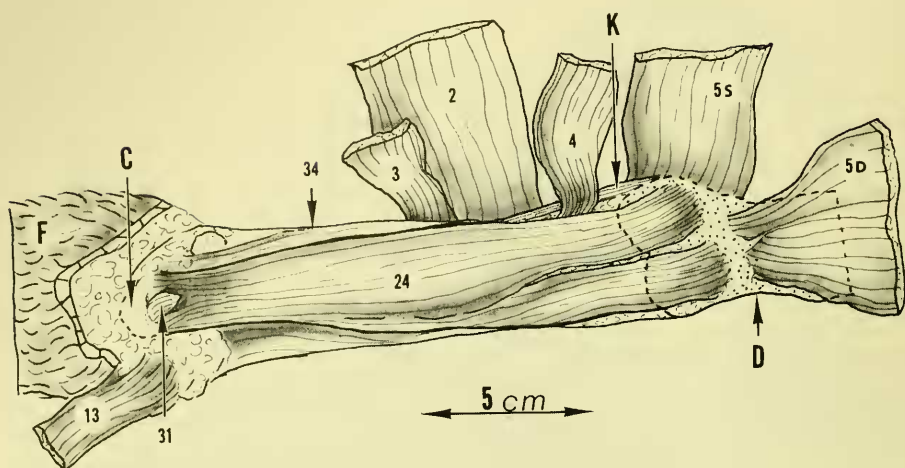


FIGURE 21. Posterior view of right knee and lower leg to show origin and insertion of the large superficial gastrocnemius (24) muscle. Note muscle insertions on the medial side of the tibia and their relation to the medial collateral ligament of the knee. Key: C, calcaneus; D, femur (distal end); F, foot; K, medial collateral ligament of knee; 2, gracilis (reflected); 3, semitendinosus (reflected); 4, semimembranosus (reflected); 5S, adductor femoris (superficial portion, reflected); 5D, adductor femoris (deep portion, reflected); 13, tenuissimus (reflected); 24, gastrocnemius; 31, plantaris; 34, tibialis posterior.

the piriformis (19), which has the bulk of its origin from the axial skeleton, thus marking the division between the two.

INSERTION. The gluteus medius terminates in a short heavy tendon inserting on the outer anterior and superior aspect of the greater trochanter of the femur.

ACTION. This muscle abducts and extends the femur.

17. *Presemimembranosus*.

A rather thin, flat, roughly triangular muscle connecting the first caudal vertebra with the femur.

ORIGIN. This muscle arises by a short strong tendon from the superior border of the transverse process of the first caudal vertebra. The muscle passes immediately over the dorsum of the ilium just above the tuberosity directed toward the femur and lies beneath the tenuissimus (13) and the caudofemoralis (11).

INSERTION. The muscle spreads out for a linear insertion on the femur (lateral ridge area) immediately posterior to the caudofemoralis (11). The insertion extends from a short distance below the greater trochanter to the distal femur, swinging somewhat medially at the epicondyle level.

ACTION. The action of this muscle is to extend the femur.

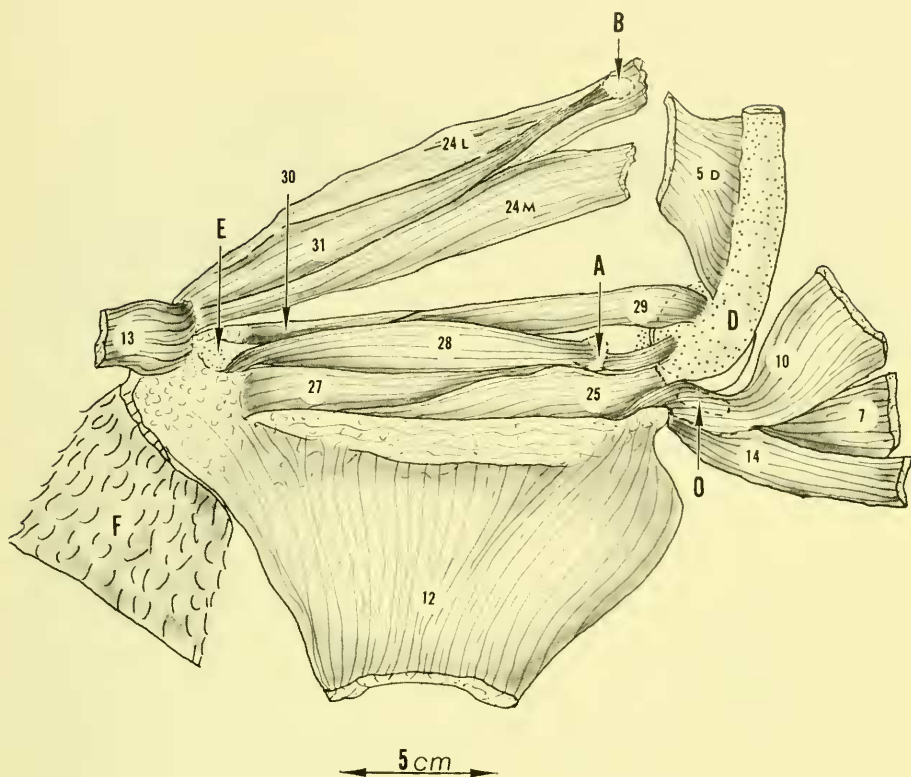


FIGURE 22. Lateral view of right knee and lower leg. The biceps femoris (12) has been reflected anteriorly to show the lower leg musculature. Both heads of the gastrocnemius (24) have been detached at their origins and the muscle reflected posteriorly and rotated somewhat to show the undersurface. Thus, the plantaris muscle (31) is exposed. Note the relationship of other lower leg muscles in this view. Key: A, fibula (head); B, sesamoid; D, femur (distal end); E, fibula (lateral malleolus); F, foot; O, patella; 5D, adductor femoris (deep portion, reflected); 7, rectus femoris (reflected); 10, vastus lateralis (reflected); 12, biceps femoris (reflected); 13, tenuissimus (reflected); 14, vastus medialis (reflected); 24L, gastrocnemius, lateral head (reflected); 24M, gastrocnemius, medial head (reflected); 25, tibialis anterior; 27, extensor digitorum longus; 28, peroneus longus; 29, peroneus digiti quinti; 30, peroneus brevis; 31, plantaris.

18. *Gluteus minimus*.

This is the lesser of the three glutei muscles and lies in close relation to the gluteus medius (16) in both origin and insertion.

ORIGIN. Muscular fibers arise from the inferior anterior aspect of the outer surface of the iliac wing, practically inseparable from the gluteus medius (16) and in close proximity to the origin of the rectus femoris (7). Toward its

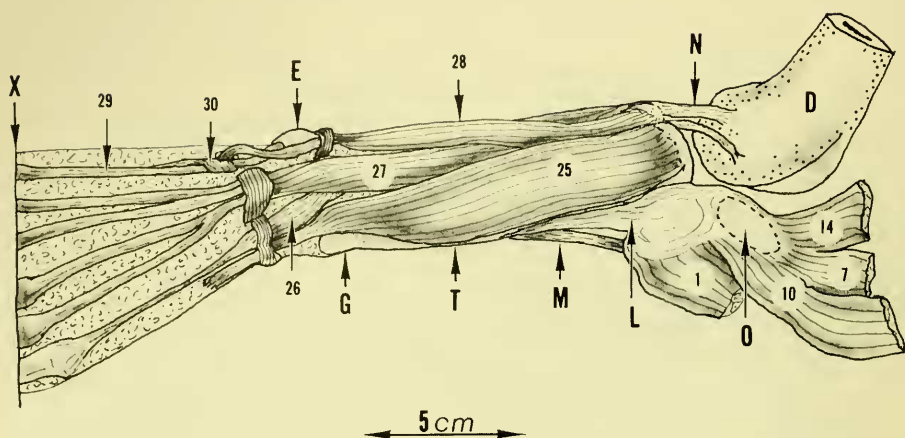


FIGURE 23. Anterolateral view of right lower extremity to show relationship of the more superficial extensor muscles. The distal femur and knee joint are shown. The medial collateral ligament has been detached from the femur. The extensor musculature of the knee has been reflected anteriorly and rotated to show the undersurface of the patella and the patellar tendon. Note the transverse ligaments at ankle level; these serve as pulleys to prevent the extensor muscles from bowstringing when the foot is dorsiflexed. Key: D, femur (distal end); E, fibula (lateral malleolus); G, tibia (medial malleolus); L, patellar tendon; M, medial collateral ligament of knee; N, lateral collateral ligament of knee; O, patella; T, tibial crest; X, metatarsophalangeal joint level; 1, sartorius (reflected); 7, rectus femoris (reflected); 10, vastus lateralis (reflected); 14, vastus medialis (reflected); 25, tibialis anterior; 26, extensor hallucis longus (proprius); 27, extensor digitorum longus; 28, peroneus longus; 29, peroneus digiti quinti; 30, peroneus brevis.

insertion, the muscle becomes a little more individualized as its short strong tendon of insertion develops.

INSERTION. Insertion by the tendon is on the outer surface of the greater trochanter, just distal and anterior to the gluteus medius (16) tendon with which it is closely associated.

ACTION. Abduction and internal rotation of the femur.

19. Piriformis.

This large strong muscle of the buttock connects the axial skeleton to the femur.

ORIGIN. Tendinous and fleshy fibers arise from the fascia overlying the spinal musculature adjacent to the wing of the ilium and from the last lumbar and first sacral vertebrae. A few deeper fleshy fibers arise from the outer surface of the ilium adjacent to the sacroiliac joint. On surface viewing, it appears inseparable from the gluteus medius (16). The muscle mass curves superiorly around the greater trochanter.

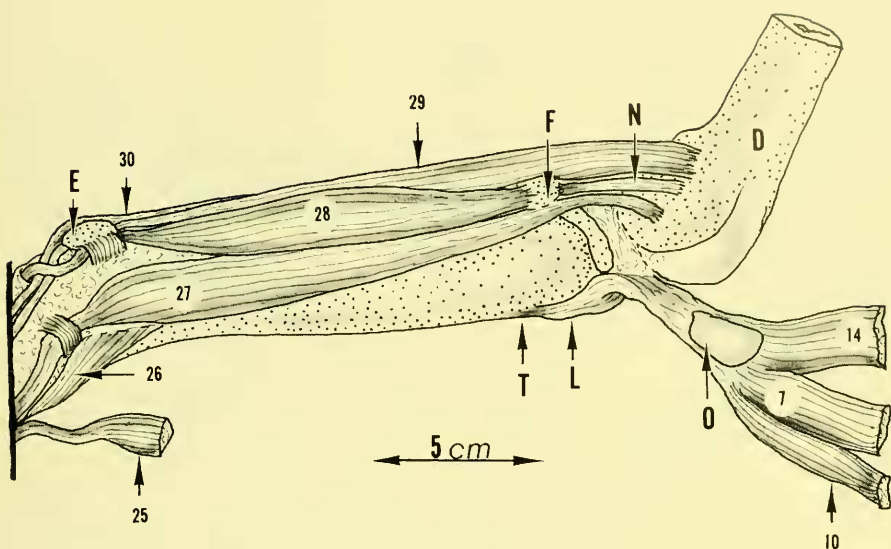


FIGURE 24. Lateral view of right lower leg including knee and ankle area. The tibialis anterior (25) has been removed from its origin and the distal portion reflected. The origin of the extensor digitorum longus (27) is now disclosed. As in figure 23, the patella and its tendon are again shown, reflected in a manner to disclose the undersurface. Key: D, femur (distal end); E, fibula (lateral malleolus); F, fibula (head); L, patellar tendon; N, lateral collateral ligament of knee; O, patella; T, tibial tuberosity; 7, rectus femoris (reflected); 10, vastus lateralis (reflected); 14, vastus medialis (reflected); 25, tibialis anterior (reflected); 26, extensor hallucis longus (proprius); 27, extensor digitorum longus; 28, peroneus longus; 29, peroneus digiti quinti; 30, peroneus brevis.

INSERTION. The short heavy tendon inserts on the outer posterior aspect of the greater trochanter appearing as a continuation of the tendon of the gluteus medius (16).

ACTION. Abduction and distention of the femur.

20. Gemelli.

These two small short muscles designated as superior and inferior join the pelvis to the femur, lying one on either side of the obturator internus tendon (23).

ORIGIN. Both muscles arise from the rim of the sciatic notch; the inferior one between the obturator internus (23) and sciatic spine, and the superior one adjacent to the obturator internus (23) to the border of the acetabulum.

INSERTION. The two gemelli join with the obturator internus (23) to form a common tendon which inserts on the medial surface of the greater trochanter as described for the obturator internus (23).

ACTION. The same action as the obturator internus (23).

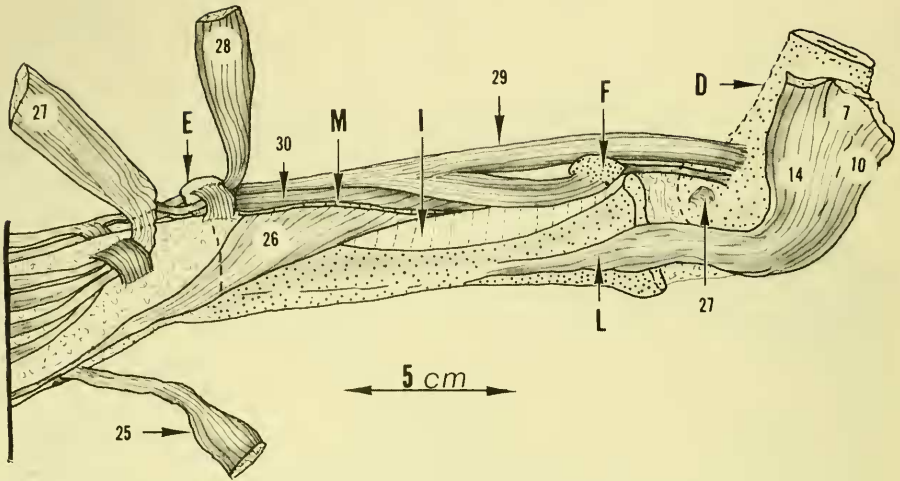


FIGURE 25. Anterolateral view of the right lower leg including knee and ankle areas. The tibialis anterior (25), the extensor digitorum longus (27), and the peroneus longus (28) have been reflected. The double origin of the peroneus digiti quinti (29) is visible. The origin of the extensor hallucis longus (proprius) (26) from the intermuscular septum is also seen. Key: D, femur (distal end); E, fibula (lateral malleolus); F, fibula (head); I, interosseous membrane; L, patellar tendon; M, intermuscular septum; 7, rectus femoris; 10, vastus lateralis; 14, vastus medialis; 25, tibialis anterior; 26, extensor hallucis longus (proprius); 27, extensor digitorum longus (reflected muscle and stump of origin); 28, peroneus longus; 29, peroneus digiti quinti; 30, peroneus brevis.

21. Obturator externus.

Lying deep to the adductor musculature, this strong pear-shaped muscle connects the distal pelvis with the greater trochanter of the femur.

ORIGIN. Fleishy fibers arise from the entire outer surface of the obturator membrane, which covers the obturator foramen, and from the adjacent bony rim of the ischium and pubis.

INSERTION. The converging fibers form a strong tendon which inserts into the posteromedial aspect of the greater trochanter just inferior to the combined tendons of the obturator internus (23) and gemelli (20).

ACTION. External rotation of the femur.

22. Iliocapsularis.

This is a small, flat, triangular muscle arising from the acetabular rim and inserting on the greater trochanter.

ORIGIN. Fleishy fibers arise from the posterior rim of the acetabulum starting immediately adjacent to the superior gemelli (20). The muscle overlies the hip joint capsule as it triangulates toward the greater trochanter.

INSERTION. A short tendon is formed and the insertion is into the medial

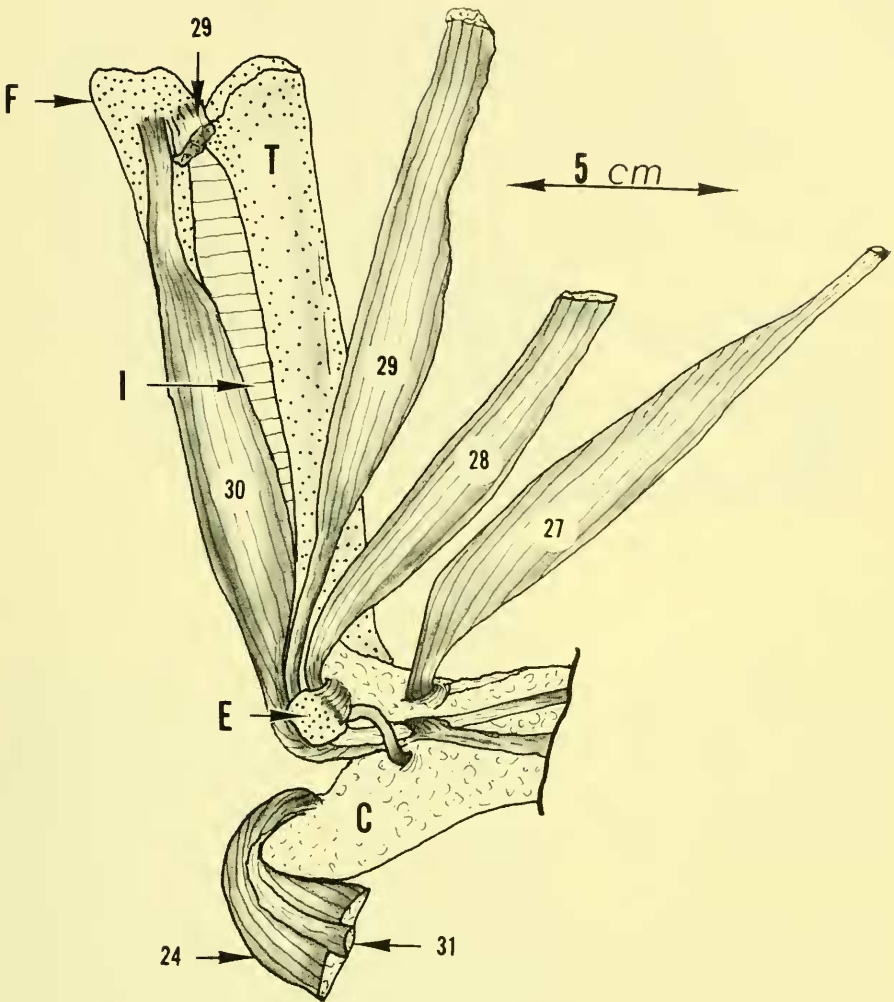


FIGURE 26. Lateral view of right lower leg and ankle. The peroneus digiti quinti (29), peroneus longus (28), and extensor digitorum longus (27) have been detached at their origins and reflected anteriorly to disclose the origin of the peroneus brevis (30). Note how, in the ankle area, the peroneus brevis (30) invests the peroneus digiti quinti (29) in a sling-like manner. Key: C, calcaneus; E, fibula (lateral malleolus); F, fibula (head); I, interosseus membranes; T, tibia; 24, gastrocnemius (reflected); 27, extensor digitorum longus; 28, peroneus longus; 29, peroneus digiti quinti (origin from fibula with muscle belly reflected); 30, peroneus brevis; 31, plantaris (reflected).

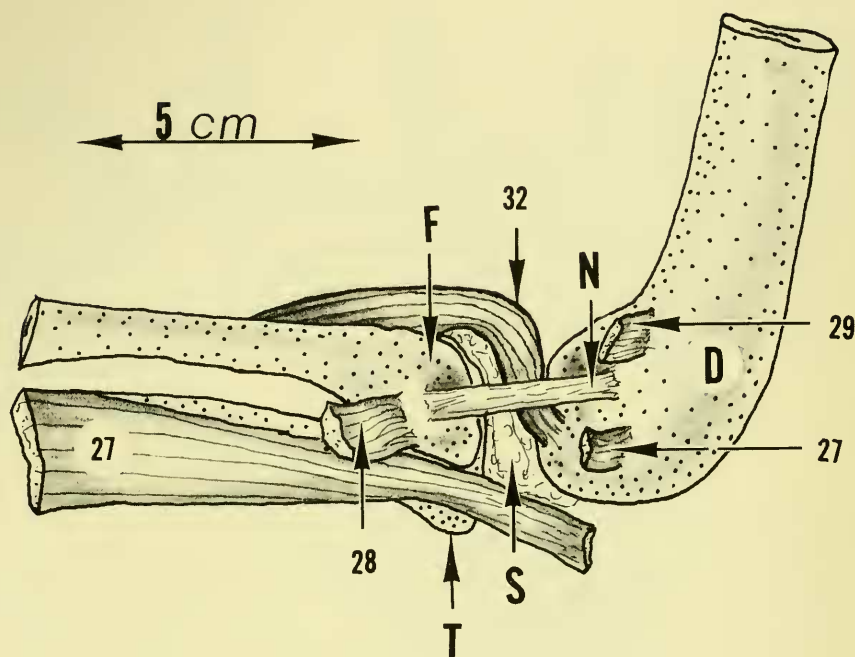


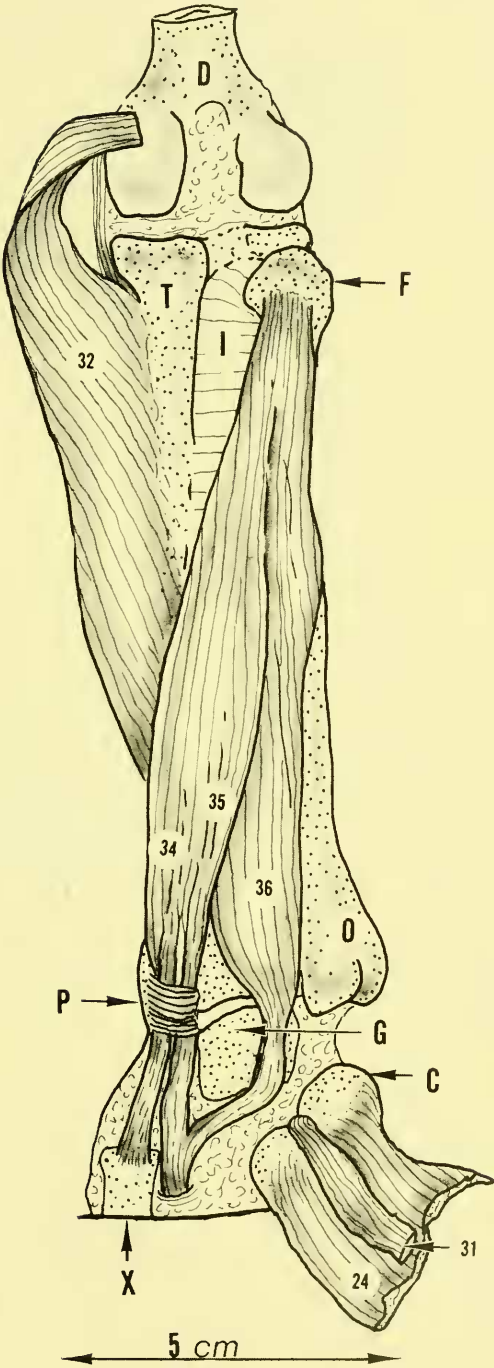
FIGURE 27. Lateral view of right knee following removal of the overlying musculature. The tendon of origin of the popliteus muscle (32) is seen. The extensor digitorum longus (27) has been divided near its origin and the distal portion reflected anteriorly. The stumps of origin of adjacent muscles are identified. A lateral semilunar cartilage is interposed between the joint surfaces. Key: D, femur (distal end); F, fibula (head); N, collateral ligament (lateral); S, semilunar cartilage; T, tibia; 27, extensor digitorum longus; 28, peroneus longus; 29, peroneus digiti quinti; 32, popliteus.

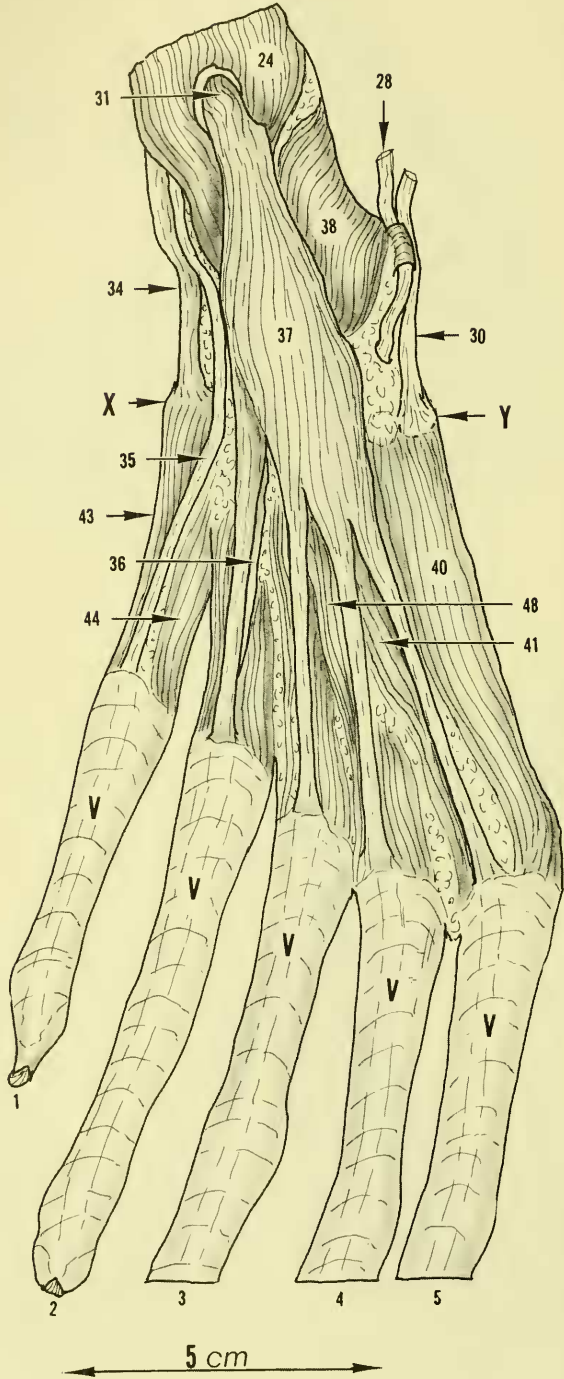
surface of the greater trochanter adjacent and anterior to the obturator (23) and gemelli (20) common tendon.

ACTION. This small muscle probably serves to stabilize the hip joint to some degree.

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FIGURE 28. Posterior view of right lower leg with knee and ankle areas included. The foot is in plantar flexion. The popliteus muscle (32) has been detached at its tendinous origin and reflected medially. The origins, dispositions, and relationships of the tibialis posterior (34), flexor hallucis longus (35), and flexor digitorum longus (36) are shown. Note tendon arrangement at ankle. Key: C, calcaneus; D, femur (distal end); F, fibula (head); G, talus; I, interosseus membrane; O, fibula (lateral malleolus); P, tibia (medial malleolus); T, tibia; X, metatarsal 1 (base); 24, gastrocnemius (reflected); 31, plantaris (reflected); 32, popliteus; 34, tibialis posterior; 35, flexor hallucis longus; 36, flexor digitorum longus.





23. *Obturator internus.*

This is a rather small flat muscle arising from the inner surface of the pelvis and extending to the femur.

ORIGIN. This muscle arises by fleshy fibers from the distal and inferior surface of the obturator membrane and from along the ischium in the region of the spine and extends anteriorly along the pubic ramus. A heart-shaped indentation seems to separate the ischial from the pubic origin. The muscle tapers abruptly to pass over the rim of the sciatic notch where it is flanked by the superior and inferior gemelli (20).

INSERTION. A common tendon is formed with the gemelli which then inserts into the medial surface of the greater trochanter beneath the insertion of the piriformis (19) and between the insertion of the iliocapsularis (22) and the obturator externus (21).

ACTION. Abduction of the femur and also external rotation of the femur.

24. *Gastrocnemius.*

This large calf muscle arises by two heads on the distal femur and inserts on the calcaneus. The muscle covers much of the posterior aspect of the lower leg.

ORIGIN. The medial head arises by heavy tendinous fibers from the posterior aspect of the distal femur just proximal to the medial condyle. The lateral head arises from a comparable position just proximal to the lateral condyle. The more medial fibers are fleshy and take origin from a slightly depressed area in the bone. The lateral tendinous fibers arise from a bony ridge along the posterior margin of the epicondyle. The sesamoid bone is in the tendon near its origin. The two heads meet about midway down the lower leg and at this point the tendon of insertion begins forming on the outer surface.

INSERTION. Distally, the tendon inserts at the tip of the calcaneus, separating slightly to let the plantaris (31) tendon pass through the groove in

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FIGURE 29. Sole of right foot with skin and subcutaneous tissue removed to show superficial musculature and tendon insertion in the proximal area. Also note fibrous flexor tendon sheaths of the digits. The plantaris (31), surrounded by the insertion of the gastrocnemius (24), emerges from a groove in the calcaneus to assist in formation of the flexor digitorum brevis (37). Key: V, fibrous flexor tendon sheath of digits; X, base of metacarpal 1; Y, base of metacarpal 5; 24, gastrocnemius; 28, peroneus longus; 30, peroneus brevis; 31, plantaris; 34, tibialis posterior; 35, flexor hallucis longus; 36, flexor digitorum longus; 37, flexor digitorum brevis; 38, quadratus plantae; 40, abductor digiti quinti; 41, adductor digiti quinti; 43, abductor hallucis; 44, adductor hallucis; 48, lumbricales.

this bone. Muscular fibers continue a short distance down the medial side of the calcaneus.

ACTION. Contraction of this muscle gives strong plantar flexion of the foot.

25. *Tibialis anterior.*

The most anterior of the anterolateral muscle group is this large roughly pyramidal-shaped muscle connecting the tibia to the foot.

ORIGIN. Fleishy fibers arise from the lateral surface of the proximal one-third of the tibia, plus a small area from the adjacent interosseus membrane. Some posterior fibers of origin span over the tendon of origin of the extensor digitorum longus (27). The muscle then tapers and passes distally in close approximation to the tibia. In the upper two-thirds, the muscle is immediately anterior to the extensor digitorum longus (27), and in the lower one-third to the extensor hallucis proprius (26). At the ankle, a strong tendon has formed which, passing under the restraining transverse tarsal ligament, deviates medially to the base of the first metatarsal.

INSERTION. The tendon inserts into the base of the first metatarsal, attaching to a lateral bony prominence.

ACTION. The action is dorsoflexion of the foot and inversion of the foot.

26. *Extensor hallucis proprius (longus).*

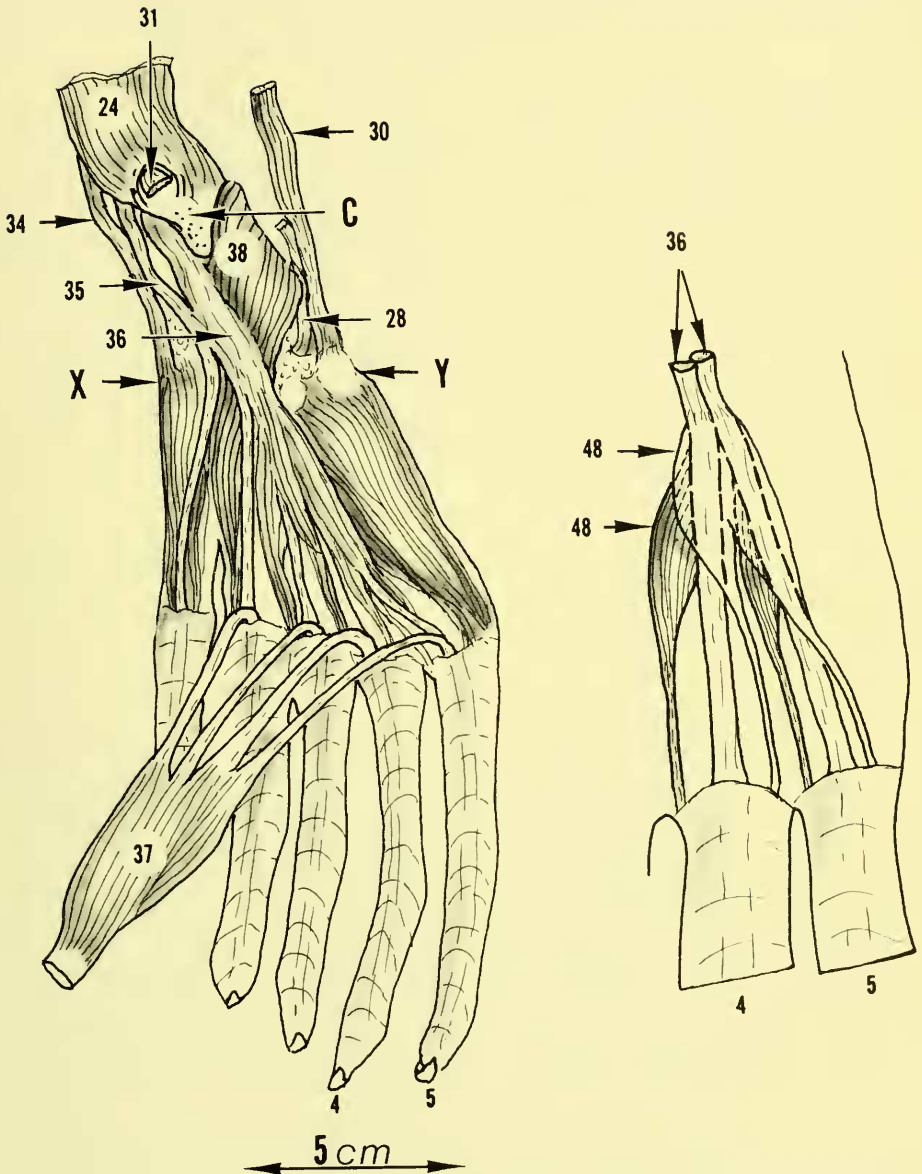
This is a relatively small muscle, somewhat triangular in shape and deep in origin, connecting the lower leg with digit 1.

ORIGIN. The muscle arises by fleshy fibers from the lower one-half of the anterior surface of the intermuscular septum and from the anterior surface of the fibula in the same area, with a few fibers arising from the very margin of the adjacent intermuscular septum. The fleshy fibers of origin triangulate as they progress toward the medial side of the ankle. The muscle continues distally in front of the ankle to about the tarsal and metatarsal junction where a thin tendon is formed. This tendon, passing under the transverse ligament of the ankle, proceeds directly along the first metatarsal.

INSERTION. On reaching the metatarsal phalangeal joint level, the tendon spreads slightly making some fascial attachments, but continues down the dorsum of the proximal phalanx to insert at the dorsum of the base of the terminal phalanx.

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FIGURE 30. Sole of right foot, identical with figure 29 except plantaris (31) has been transected at the calcaneus permitting the flexor digitorum brevis (37) to be reflected distally exposing the flexor digitorum longus (36) and lumbricale (48) musculature. The sketch at the right is a diagrammatic enlarged view of the flexor digitorum longus (36) for



digits 4 and 5 to show the two superficial lumbrical muscles (48) (unshaded) which arise from these tendons and pass to the ulnar side of each digit respectively. Key: C, calcaneus; X, metatarsal 1 (base); Y, metatarsal 5 (base); 24, gastrocnemius; 28, peroneus longus; 30, peroneus brevis; 31, plantaris; 34, tibialis posterior; 35, flexor hallucis longus; 36, flexor digitorum longus; 37, flexor digitorum brevis (reflected); 38, quadratus plantae; 48, lumbricales.

ACTION. Action of this tendon is to extend both the proximal and distal joints of the first digit.

27. *Extensor digitorum longus*.

This is a spindle-shaped muscle in the lateral aspect of the lower leg, which connects the femur to the digits.

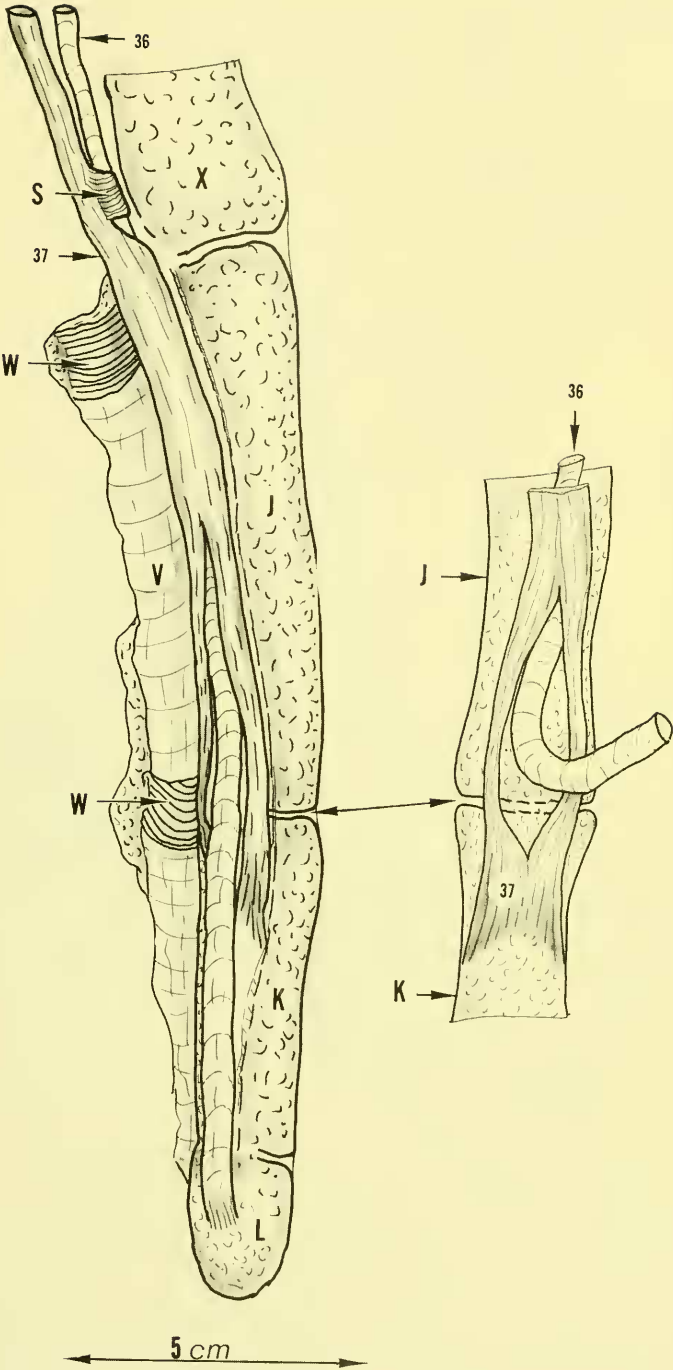
ORIGIN. Origin of this muscle is by long, strong, rounded tendons from the lateral aspect of the distal femur adjacent to the articular surface of the knee. Crossing the knee joint, the tendon lies in the groove of the upper tibia and under the muscular fibers of origin of the tibialis anterior (25). The spindle-shaped muscle belly then forms and courses the length of the lower leg between the tibialis anterior (25) and the peroneus digiti quinti (29), and overlying the extensor hallucis proprius (26). Just above the ankle, the tendon of insertion develops and passes under the transverse ankle ligament where it divides promptly into four separate tendons which pass directly toward digits 2, 3, 4, and 5.

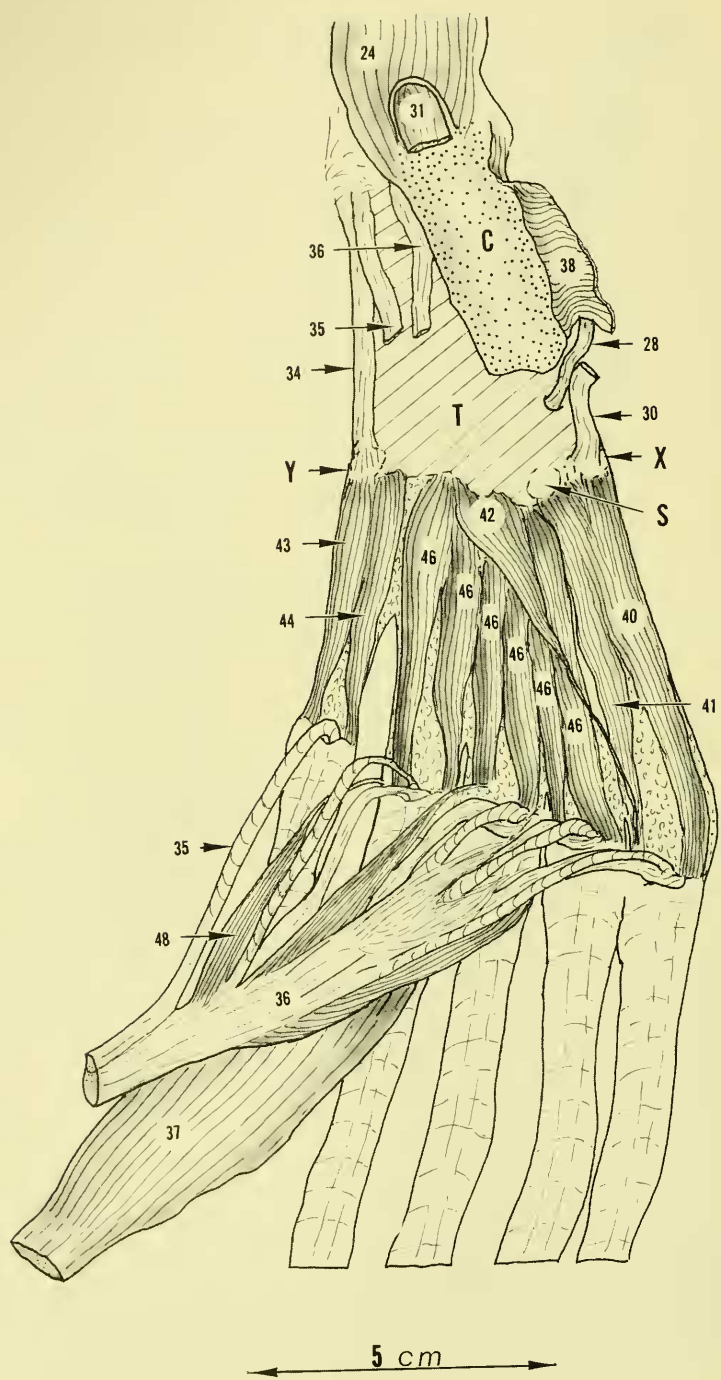
INSERTION. On reaching the metatarsal phalangeal joint level, the tendon enters the extensor aponeurosis of the respective digit. The tendon fibers continue distally in the aponeurosis and most of them insert into the base of the middle phalanx, but some may continue to the distal joint (see details of extensor aponeurosis).

→

FIGURE 31. Anterolateral view of the fifth digit with the fibrous flexor tendon sheath (V) reflected to show relationship and insertions of flexor digitorum longus (36) and flexor digitorum brevis (37). This is the pattern for digits 2 to 5. Note the concentration of transverse connective tissue fiber strands (W) in flexor tendon sheath (V) to form a pulley mechanism for the flexor tendons. Also note the sling-type structure (S) from flexor digitorum brevis (37) surrounding flexor digitorum longus (36) at metatarsal head level. Digit 1, of course, is without a flexor digitorum brevis tendon. The diagrammatic sketch to the right represents an anterior view at proximal interphalangeal joint level showing the manner of insertion of flexor digitorum brevis (37) at the base of the middle phalanx. Key: J, proximal phalanx; K, middle phalanx; L, distal phalanx; S, sling-like structure of brevis surrounding longus; V, flexor tendon sheath; W, flexor tendon sheath pulleys; X, metatarsal; 36, flexor digitorum longus; 37, flexor digitorum brevis.

FIGURE 32. Sole of right foot with flexor digitorum brevis (37) and flexor digitorum longus (36) reflected to include the lumbricales (48), thus exposing the deep layer of intrinsic muscles and the ventral joint level of the tarsus. Key: C, calcaneus; S, sesamoid (base of metatarsal 5); T, capsule of tarsus; X, base of metatarsal 5; Y, base of metatarsal 1; 24, gastrocnemius; 28, peroneus longus; 30, peroneus brevis (reflected); 31, plantaris; 34, tibialis posterior; 35, flexor hallucis longus (reflected); 36, flexor digitorum longus (reflected); 37, flexor digitorum brevis (reflected); 38, quadratus plantae (reflected); 40, abductor digiti quinti; 41, adductor digiti quinti; 42, opponens digiti quinti; 43, abductor hallucis; 44, adductor hallucis; 46, interossei; 48, lumbricales.





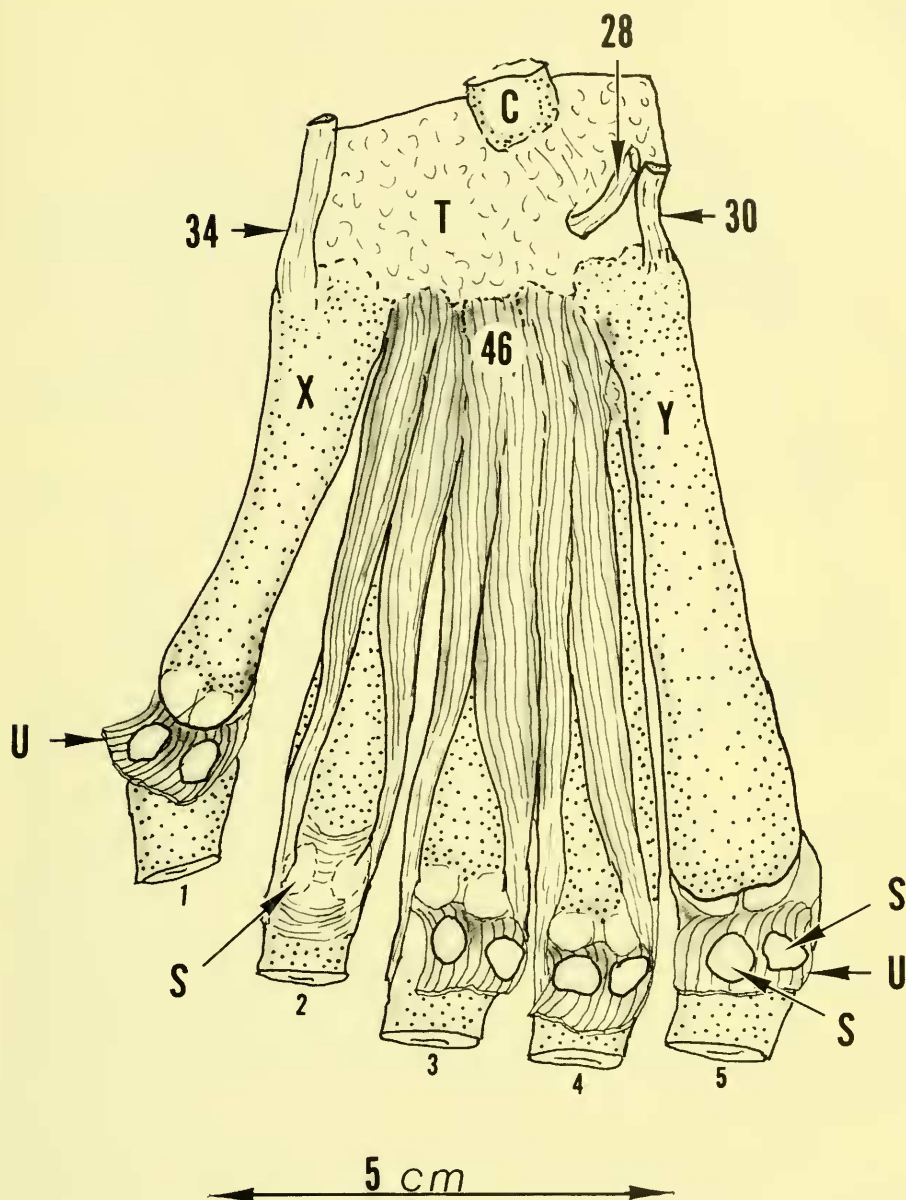


FIGURE 33. Plantar view of metatarsal area of right foot. All small muscles have been removed, except the interossei (46). The plantar joint capsules of the metacarpophalangeal joints, except for digit 2, have been detached from the metacarpal and reflected distally, thus exposing the joints and revealing the two sesamoid bones in the capsule. For digit 2, the plantar joint capsule remains in place. Key: C, calcaneus; S, sesamoid bone; T, plantar capsule of tarsus; U, plantar joint capsule of metatarsophalangeal joint, reflected; X, metatarsal 1; Y, metatarsal 5; 28, peroneus longus; 30, peroneus brevis; 34, tibialis posterior; 46, interossei.

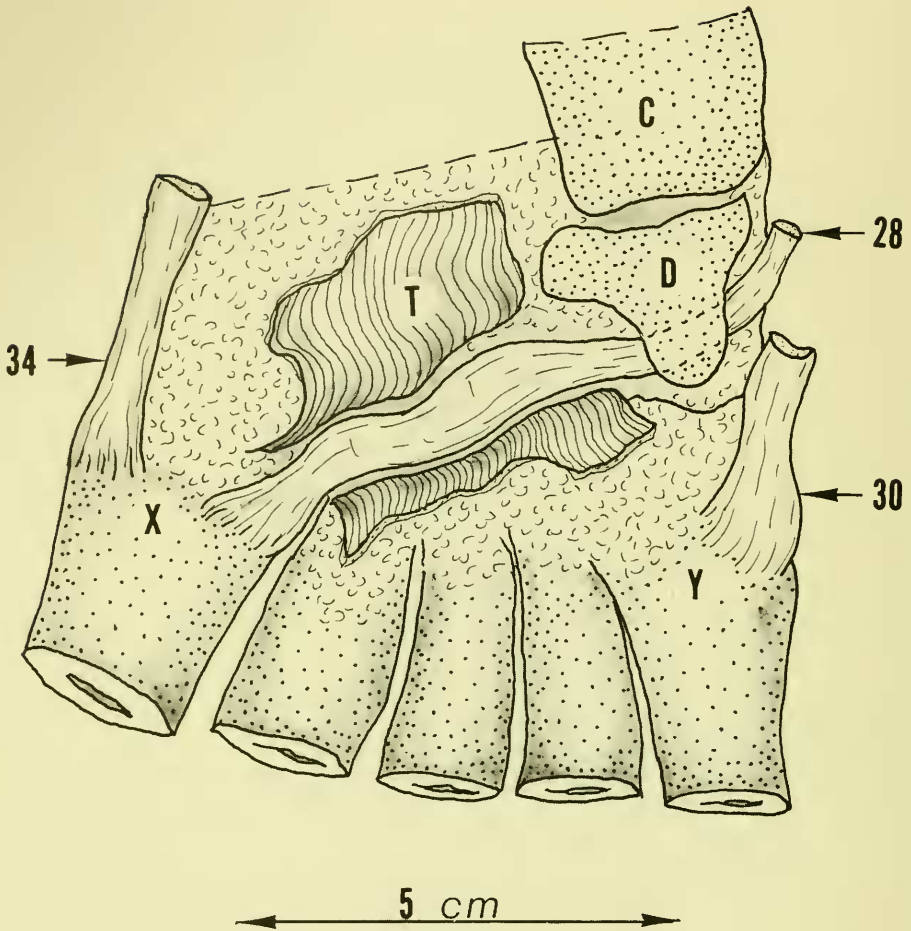


FIGURE 34. Plantar view of metatarsotarsal area. All small intrinsic muscles have been removed. The plantar joint capsule has been incised and reflected proximally to reveal the course of the peroneus longus (28) tendon as it passes in a groove in the cuboid to cross the foot and insert at the base of the first metatarsal. Key: C, calcaneus; D, cuboid; T, capsule of tarsus (reflected); X, base of metatarsal 1; Y, base of metatarsal 5; 28, peroneus longus; 30, peroneus brevis; 34, tibialis posterior.

ACTION. The extensor action through the aponeurosis is to extend the proximal or metatarsal phalangeal joint, and also the middle and distal joints providing the metatarsal phalangeal joint is not in hyperextension.

28. Peroneus longus.

This spindle-type muscle connects the upper tibia with the foot.

ORIGIN. The muscle arises with mostly tendinous fibers from the anterior,

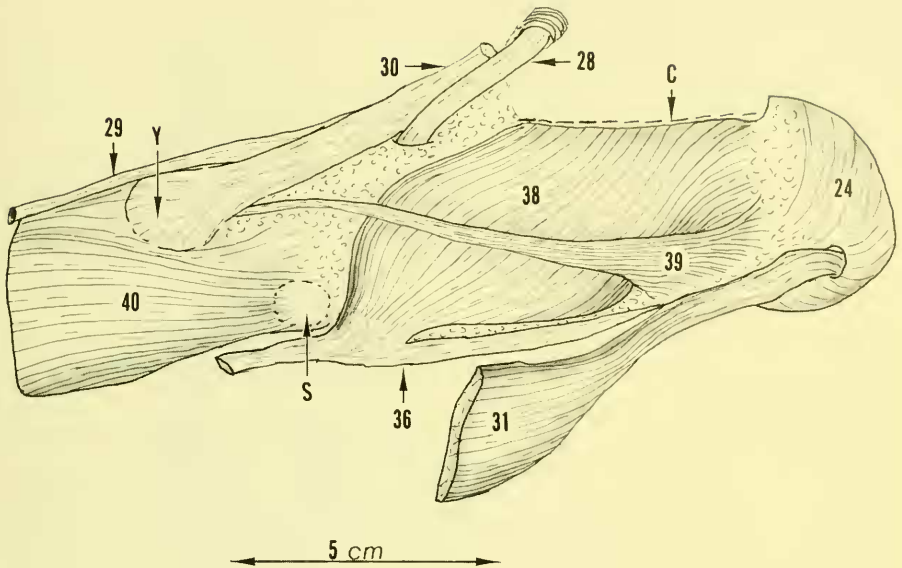


FIGURE 35. Posterolateral aspect of left ankle in an enlarged view to show the diminutive calcaneometatarsalis muscle (39), which was not visualized on the right side. Note also the quadratus plantae (38) joining into the flexor digitorum longus (36). Key: C, margin of calcaneus; S, sesamoid; Y, base of metatarsal 5; 24, gastrocnemius; 28, peroneus longus; 29, peroneus digiti quinti; 30, peroneus brevis; 31, plantaris (reflected); 36, flexor digitorum longus; 38, quadratus plantae; 39, calcaneometatarsalis; 40, abductor digiti quinti.

lateral, and inferior surfaces of the head of the fibula. Passing distally down the lower leg in the lateral position, the muscle lies between the extensor digitorum longus (27) and the peroneus digiti quinti (29). At the ankle, a strong round tendon develops which passes over the anterior surface of the lateral malleolus, under strong restraining ligament, and at this point the tendon overlies the peroneus digiti quinti (29) tendon and the peroneus brevis (30) tendon. Passing through a groove (perineal groove of the cuboid), the tendon dives deeply into the sole of the foot.

INSERTION. The tendon lies in its own sheet as it crosses the foot, buried deep in the plantar fibrous capsule of the tarsal area. Its actual insertion is into the base of the first metatarsal on the ventral aspect.

ACTION. The action of this muscle is to plantar flex and pronate the foot.

29. Peroneus digiti quinti.

This is a strong fleshy muscle of double origin, which joins the femur and fibula to the fifth digit.

ORIGIN. Origin of this muscle is by two heads; the larger and most posterior head arises by fleshy fibers from the lateral side of the distal femur

and immediately posterior to the lateral collateral knee ligament and from a very slight bony prominence at the site. The lesser and more anterior head arises from the anterolateral surface of the very proximal portion of the fibular shaft and immediately adjacent to the peroneus longus (28) origin. Two muscle bellies join at about the junction of the upper and middle thirds of the fibula and continue distally between the peroneus brevis (30) and longus (28) muscles. Near the lateral malleolus, an ovoid strong tendon forms which then passes posteriorly and deep in the groove behind the malleolus to continue along the lateral side of the ankle passing under the peroneus longus (28) tendon. The tendon of the peroneus brevis (30) lies immediately posterior and, near its insertion at the base of metatarsal 5, a fibrous-type investment sheath arises and surrounds the tendon of the peroneus digiti quinti as the restraining ligament.

INSERTION. The peroneus digiti quinti tendon continues distally along the lateral border of the fifth metatarsal to the proximal joint level, then on distally to enter the extensor aponeurosis of this digit. The tendon continues to stay well to the lateral side, and at middle joint level it inserts into the base of the middle phalanx.

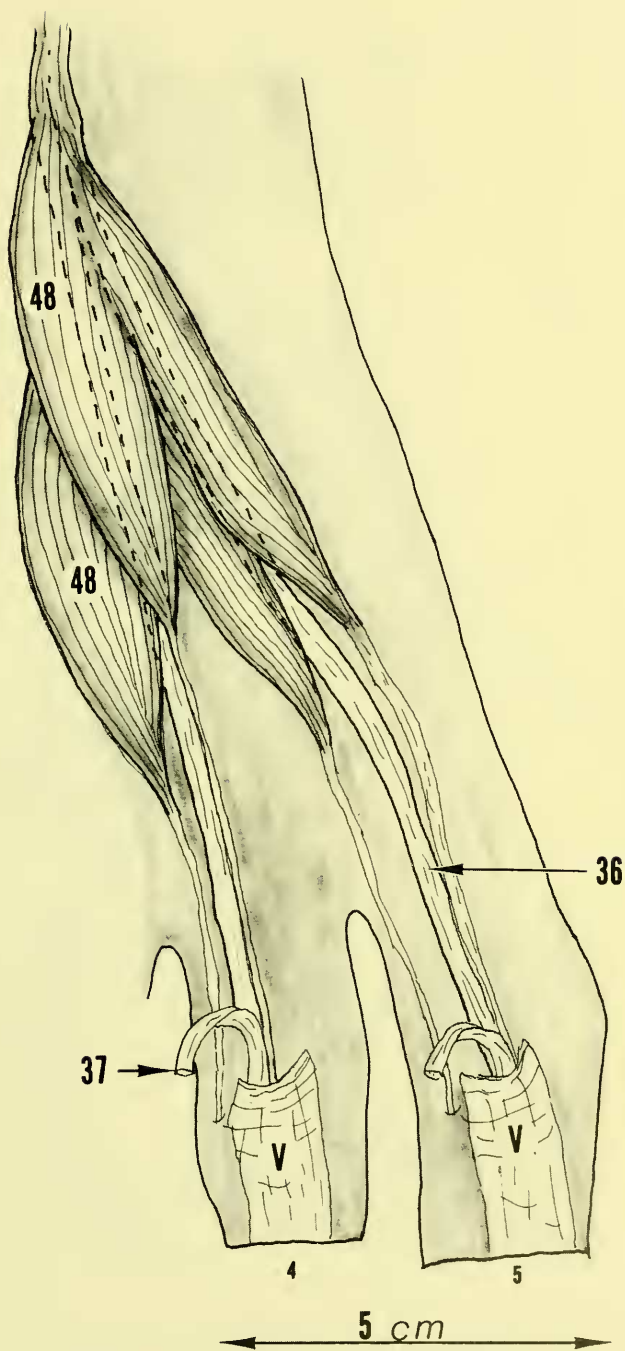
ACTION. In view of the location of this tendon, it would serve as an extensor of the metatarsal phalangeal joint of the fifth digit when working with the extensor digitorum longus (27), but when working independently it would

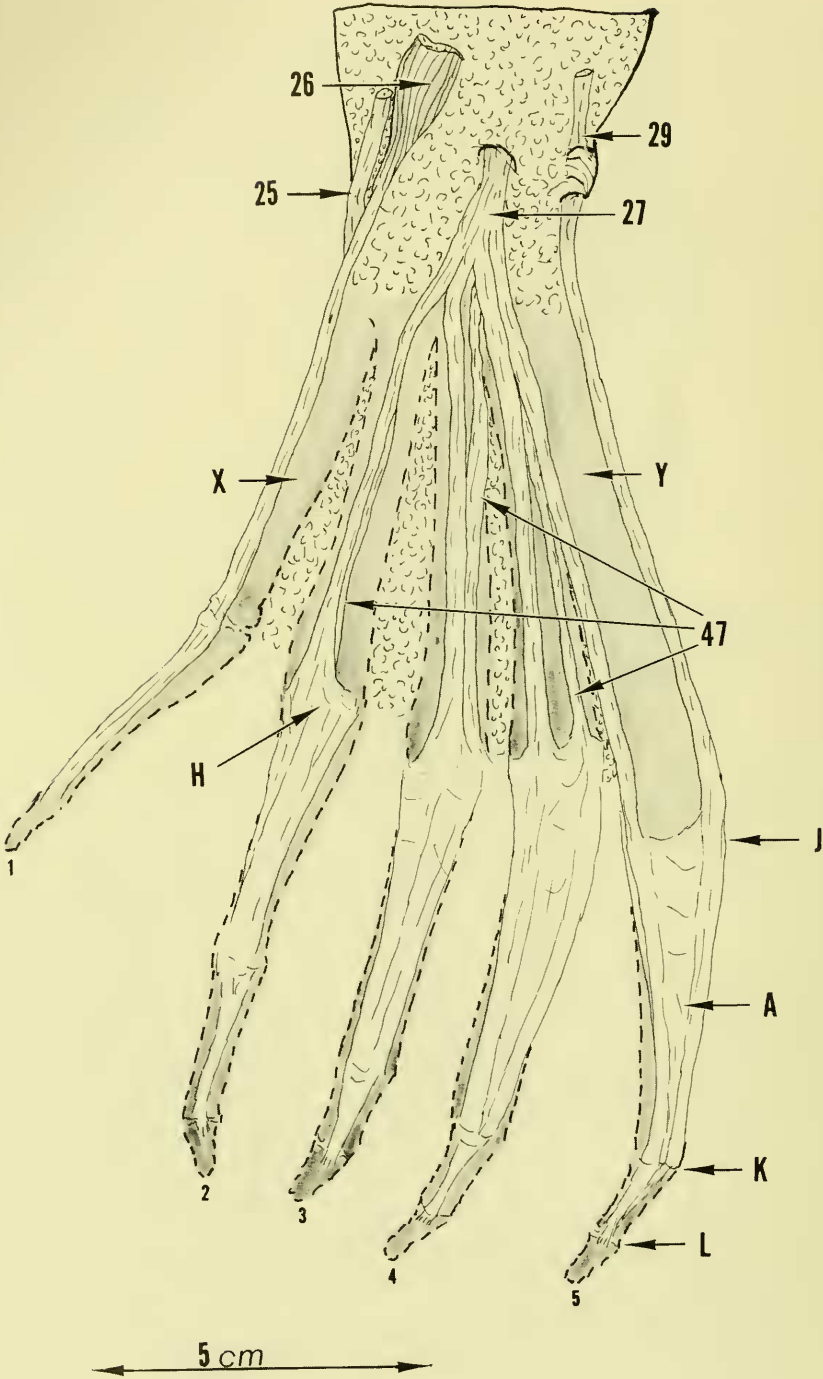
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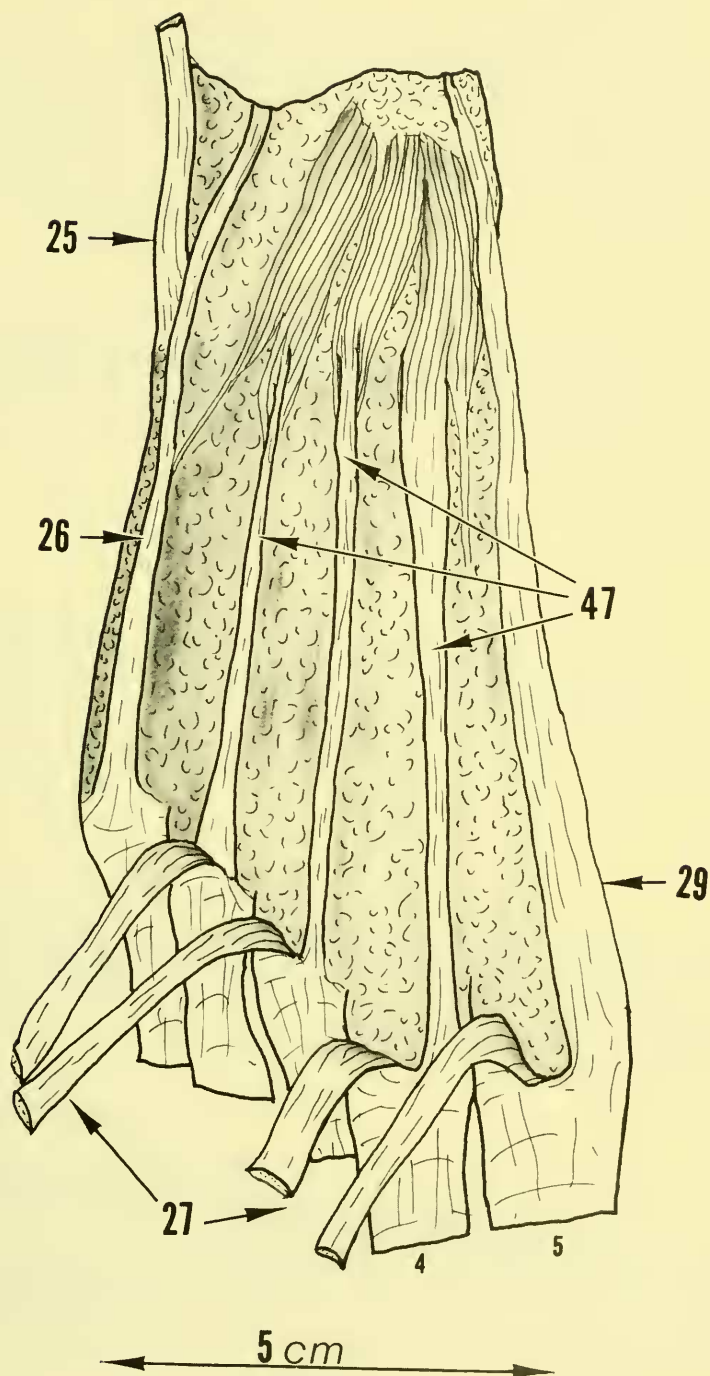
FIGURE 36. Semidiagrammatic plantar view of fourth and fifth digits of right foot to show origin and insertion of the two superficial lumbrical muscles (48). The flexor digitorum brevis (37) tendons are reflected just prior to their entering the flexor tendon sheath. Note the small tendons of the more superficial lumbrical muscles (48) joining the flexor digitorum brevis (37) tendon on the lateral side at this site. Key: V, flexor tendon sheath (muscles); 36, flexor digitorum longus; 37, flexor digitorum brevis; 48, lumbricales (both deep and superficial).

FIGURE 37. Dorsal view of left foot. All skin and subcutaneous tissue have been removed, including the interdigital webbing. Visible is the distribution pattern of the toe extensors, and the extensor aponeuroses over the dorsum of digits 2, 3, 4, and 5. The proximal end of the aponeurosis forms the tendinous hood about the metatarsophalangeal joint. Key: A, extensor aponeurosis; H, extensor hood; J, metatarsophalangeal joint level; K, proximal interphalangeal joint level; L, distal interphalangeal joint level; X, metatarsal 1; Y, metatarsal 5; 25, tibialis anterior; 26, extensor hallucis longus (proprius); 27, extensor digitorum longus; 29, peroneus digiti quinti; 47, extensor digitorum brevis.

FIGURE 38. Anterior or dorsal view of left foot. The extensor digitorum longus (27) tendons have been reflected distally to show the origin of the extensor digitorum brevis musculature (47). Note that the extensor digitorum brevis (47) has good representation for digits 2, 3, and 4. The token representation to digits 1 and 5 has tiny tendons which appear to join into the extensor digitorum longus (27) for each digit. Key: 25, tibialis anterior; 26, extensor hallucis longus (proprius); 27, extensor digitorum longus (reflected); 29, peroneus digiti quinti; 47, extensor digitorum brevis.







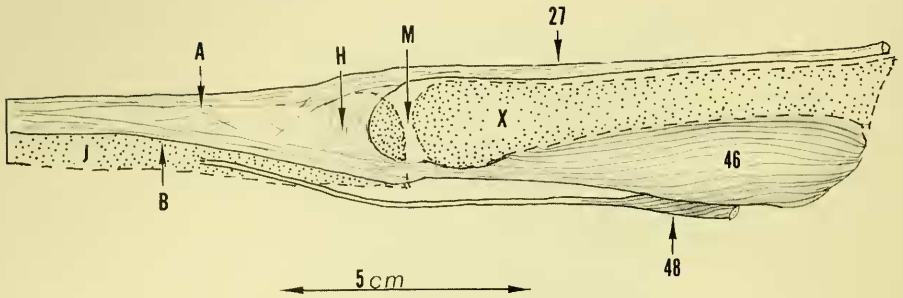


FIGURE 39. An enlarged medial view of the second digit of the right foot to show the usual relationship of long extensor (27), interossei (46), and lumbrical (48) tendons. Note the tendinous hood about the metatarsophalangeal joint, and the extensor aponeurosis, which continues distally. The tendon of the interosseus (46) forms the lateral band of the aponeurosis. The small lumbrical (48) tendon inserts into the proximal phalanx. Key: A, extensor aponeurosis; B, lateral band of extensor aponeurosis; H, extensor hood; J, proximal phalanx; M, metatarsophalangeal joint; X, metatarsal; 27, extensor digitorum longus; 46, interossei; 48, lumbricales.

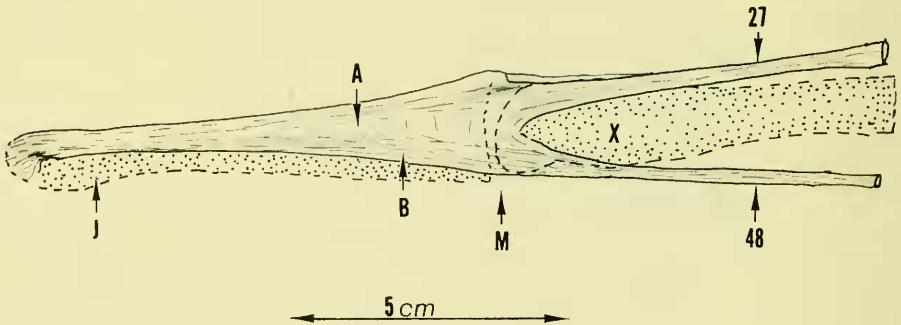
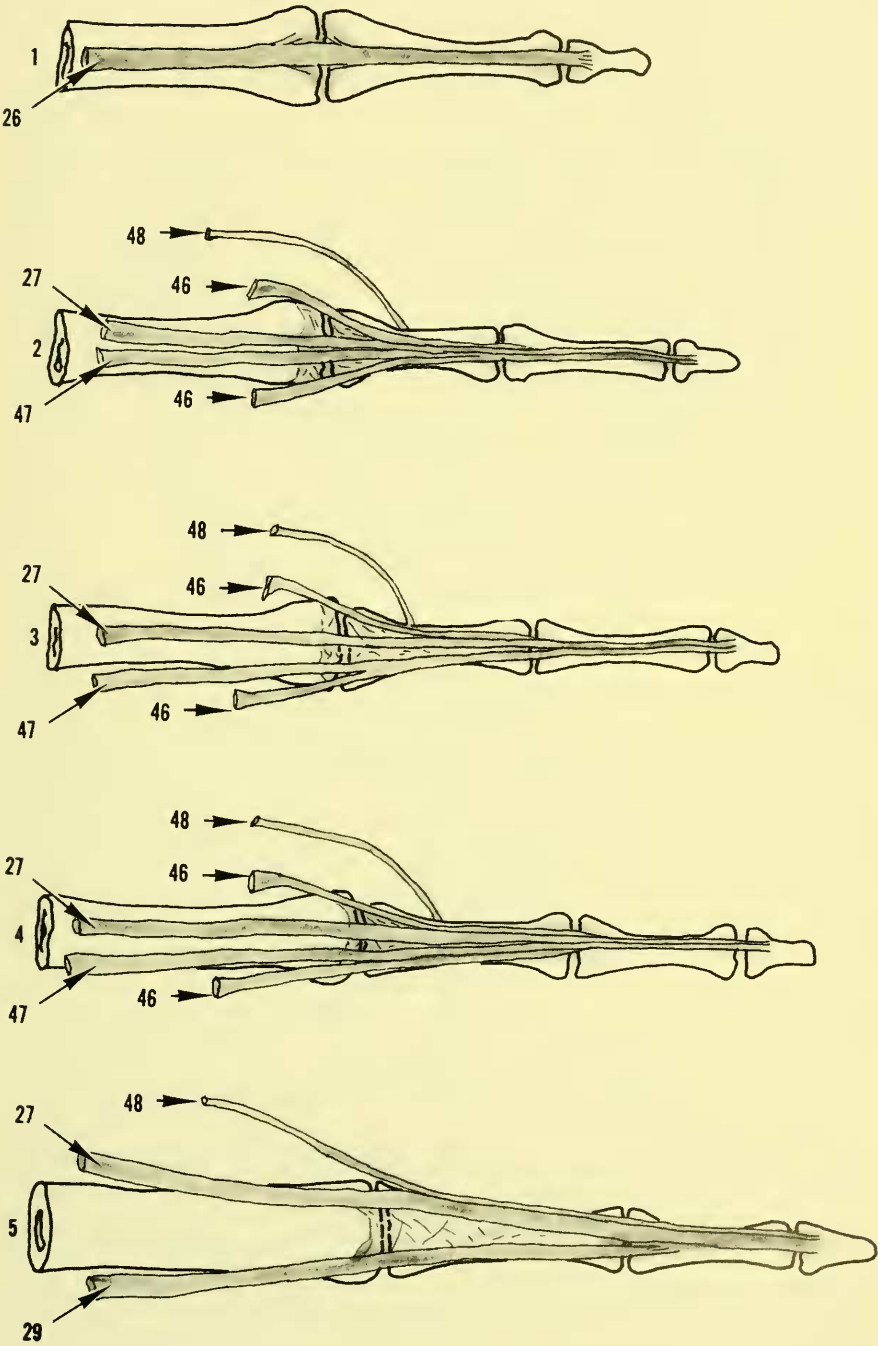


FIGURE 40. Medial view of the fifth digit of the right foot. Note that there is no interosseus muscle for this digit, and that the lumbrical (48) tendon, instead of inserting into the proximal phalanx, joins the extensor (27) aponeurosis to form the lateral band on the medial side. Key: A, extensor aponeurosis; B, lateral band of extensor aponeurosis; J, proximal phalanx; M, metatarsophalangeal joint; X, metatarsal 5; 27, extensor digitorum longus; 48, lumbricales.

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FIGURE 41. Diagrammatic representation of the extensor mechanism of the digits of the right foot. Note that only for digits 2, 3, and 4 are interossei (46) and extensor digitorum brevis (47) present. For digit 5, the peroneus digiti quinti (29) serves as an extensor digitorum brevis, and the lumbrical (48) joins the extensor aponeurosis instead of inserting directly into the proximal phalanx. Digit 1 shows the simple arrangement of a single extensor tendon made possible by the presence of only two joints. Key: 26, extensor hallucis longus (proprius); 27, extensor digitorum longus; 29, peroneus digiti quinti; 46, interossei; 47, extensor digitorum brevis; 48, lumbricales.



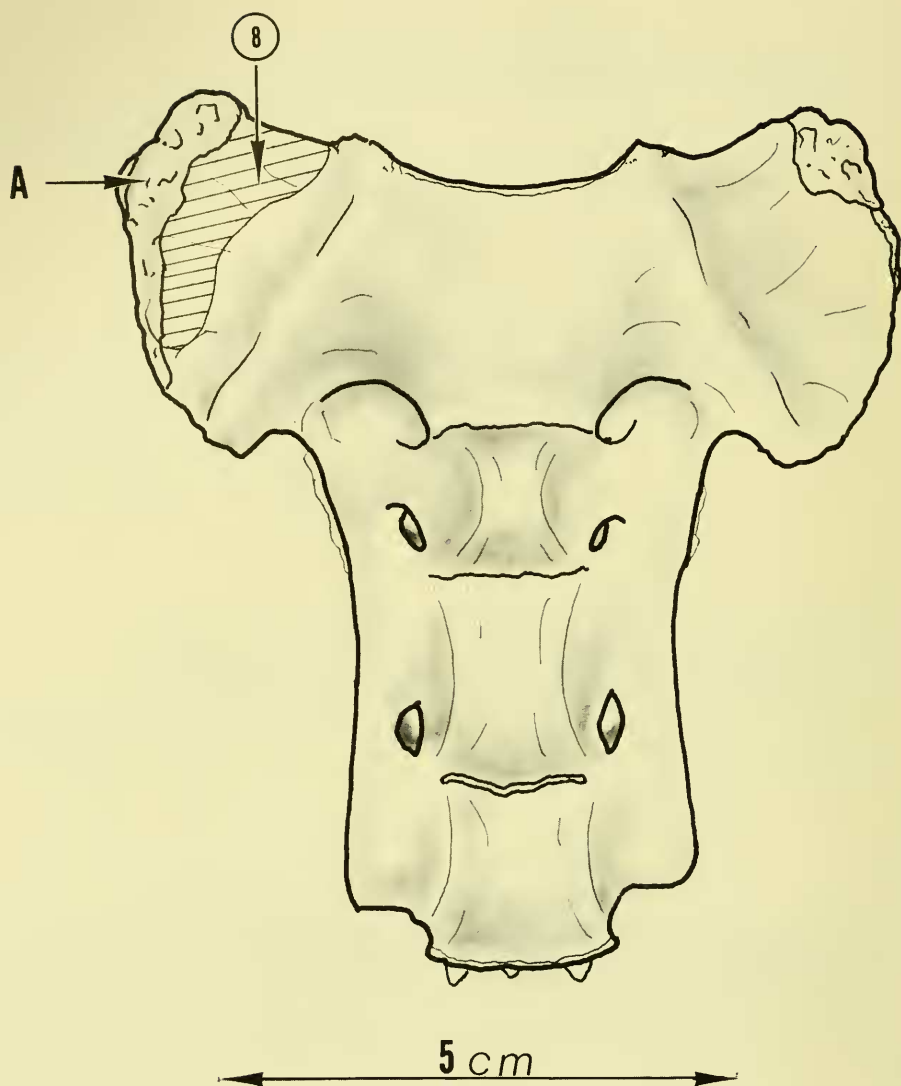


FIGURE 42. Anterior view of the sacrum. Key: A, sacroiliac joint; 8, iliopsoas (origin).

serve to abduct digit 5 at the metatarsal phalangeal joint level. Actually, the action would be mostly abduction from the adduction position, since abduction *per se* of this joint is practically nil past the straight line with the metatarsal.

30. *Peroneus brevis*.

This is the most posterior of the peroneal group connecting the fibula with the foot.

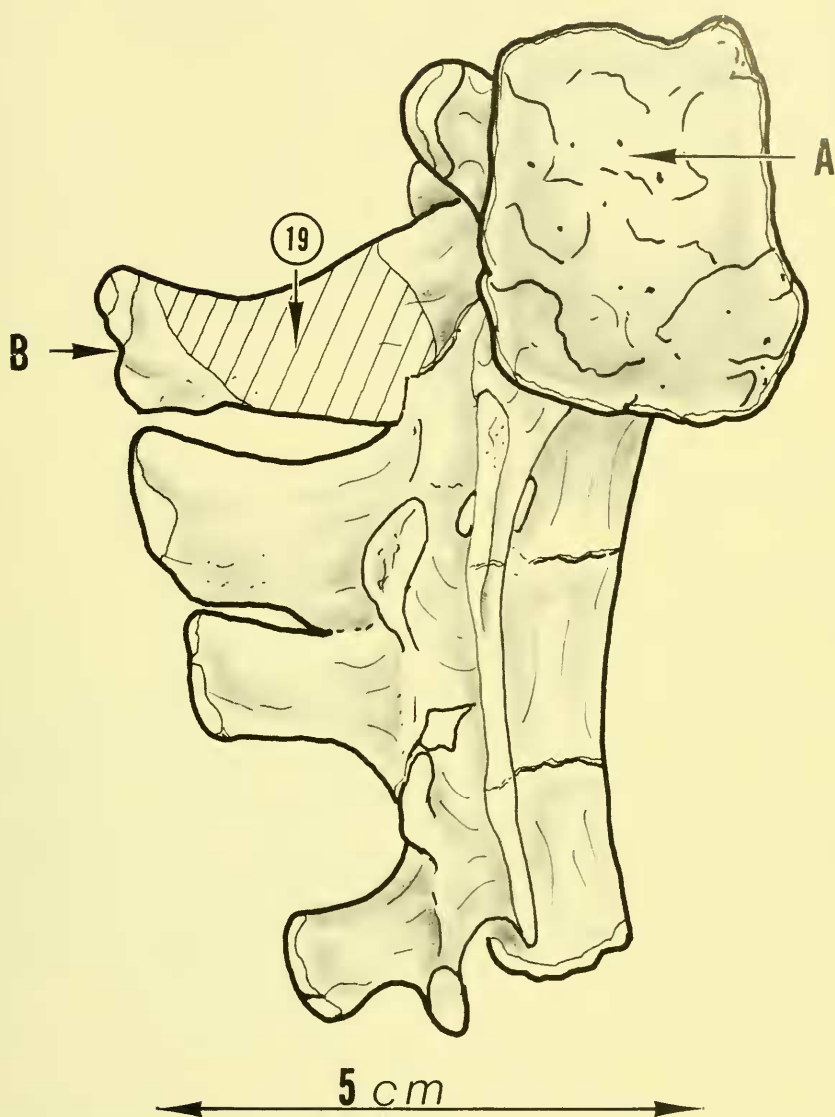


FIGURE 43. Right lateral view of sacrum. Key: A, sacroiliac joint; B, spinous process of first sacral vertebra; 19, piriformis (origin).

ORIGIN. The muscle arises from the distal two-thirds of the shaft of the fibula from the lateral, posterior, and anterior surfaces and from the posterior side of the interosseus membrane in this area. The origin is by fleshy fibers for the most part. Superiorly and posteriorly, the origin is in close association

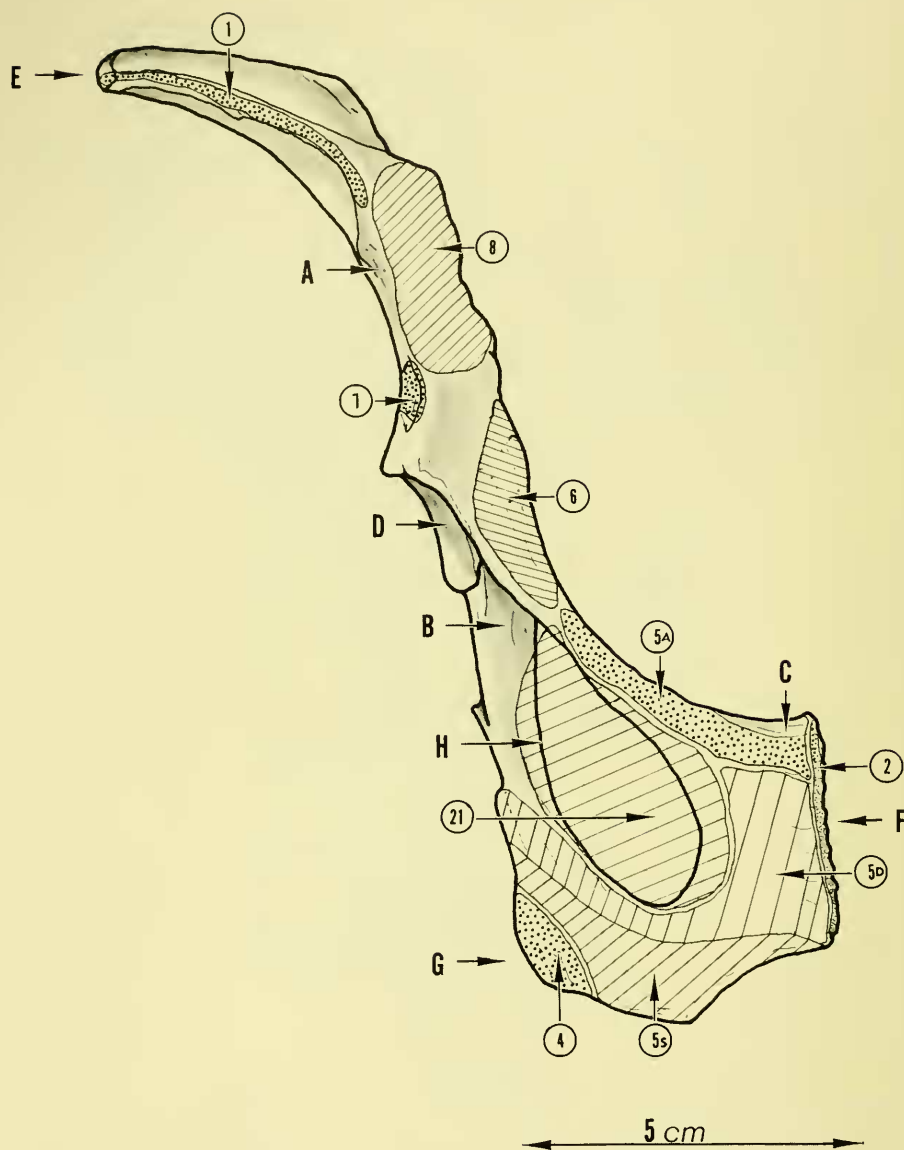


FIGURE 44. Anterior view of right pelvis. Key: A, ilium; B, ischium; C, pubis; D, acetabulum; E, iliac crest; F, symphysis pubis; G, ischial tuberosity; H, obturator foramen; 1, sartorius (origin); 2, gracilis (origin); 4, semimembranosus (origin); 5A, adductor longus (origin); 5D, adductor femoris (deep portion—origin); 5S, adductor femoris (superficial portion—origin); 6, pectineus (origin); 7, rectus femoris (origin); 8, iliopsoas (origin); 21, obturator externus (origin).

with the flexor digitorum longus (36). The muscle then courses distally along the side and posterior to the peroneus digiti quinti (29). Near the ankle, a heavy tendon forms which rounds the lateral malleolus posterior to, but in a common sheath with, the tendon of the peroneus digiti quinti (29). A few muscle fibers on the posterior surface of the tendon continue with the tendon around the lateral malleolus.

INSERTION. It continues distally along the lateral side of the ankle under the peroneus longus (28) tendon to the base of metatarsal 5. Near its insertion, the fibrous sheath-like structure envelops the more anterior peroneus digiti quinti (29) tendon for a short distance.

ACTION. Eversion and plantar flexion of the foot.

31. *Plantaris.*

This muscle bears a close association with the lateral head of the gastrocnemius (24) and, for most of its distance in the muscular area, it is inseparable from this lateral head.

ORIGIN. Distinct tendinous fibers arise in conjunction with the origin of the lateral head. These fibers are the most lateral ones, and from the origin to midway to the ankle distinct separation of the lateral head does not occur. At midpoint, however, the muscle becomes separate and moves medially to the midline. A tendon of insertion begins to form at this point. By the time the calcaneus is reached, a distinct, somewhat flattened tendon has formed which lies directly under the tendon of the gastrocnemius (24).

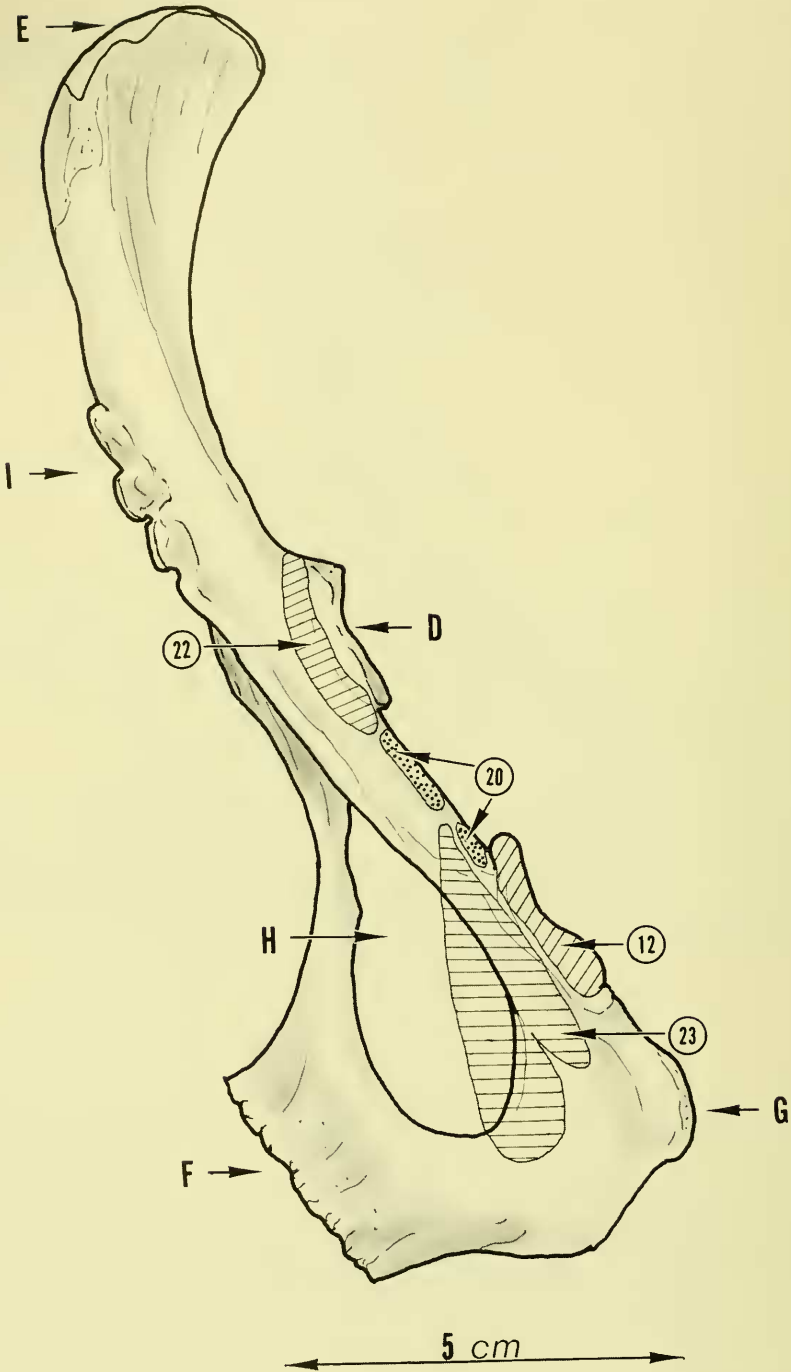
INSERTION. The tendon now enters a groove at the posterior end of the calcaneus as the gastrocnemius (24) tendon is inserting to either side. Passing through the tendon of the gastrocnemius (24), the plantaris tendon reaches the sole of the foot where it enters into the flexor digitorum brevis (37) mechanism.

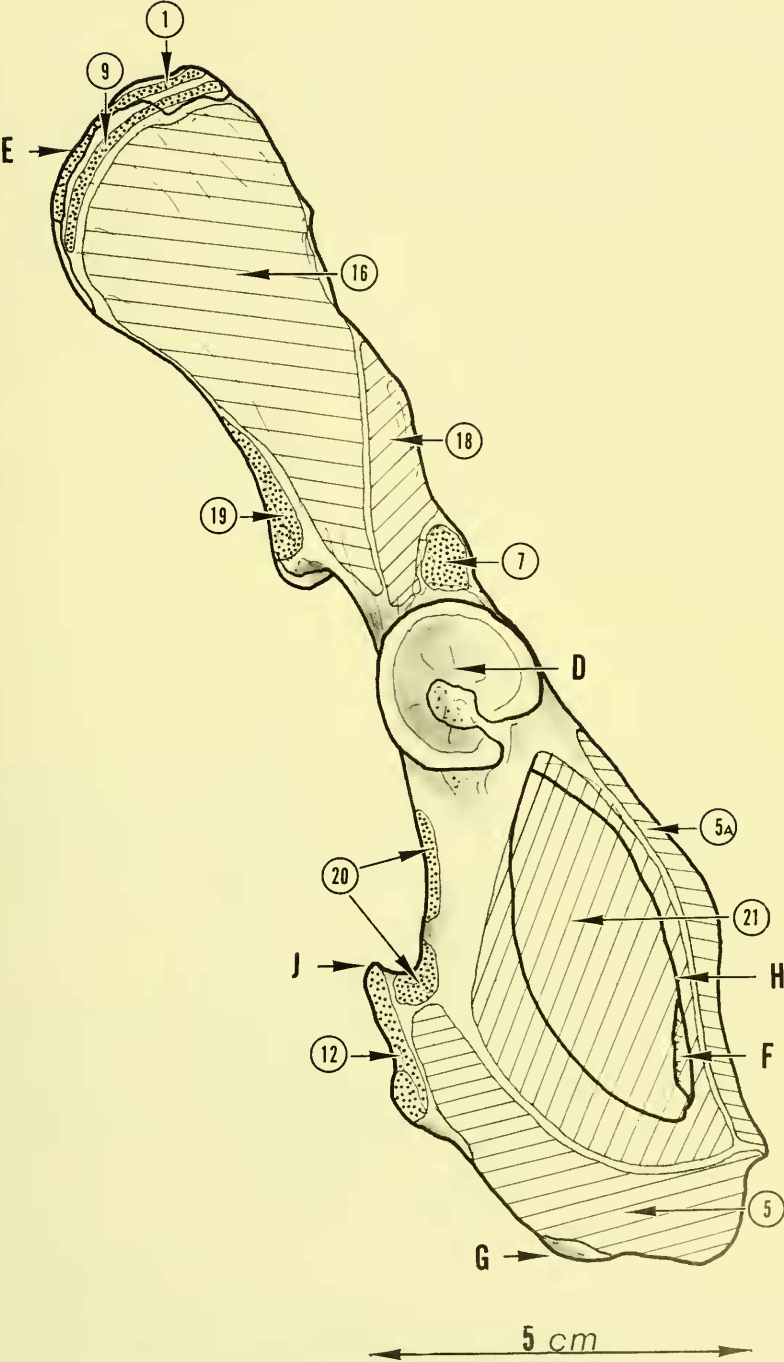
ACTION. This tendon would serve to plantar flex the foot and to also flex the digits through the flexor digitorum brevis (37) complex.

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FIGURE 45. Posterior view of right pelvis. Key: D, acetabulum; E, iliac crest; F, symphysis pubis; G, ischial tuberosity; H, obturator foramen; I, sacroiliac joint; 12, biceps femoris (origin); 20, gemelli (origin); 22, iliocapsularis (origin); 23, obturator internus (origin).

FIGURE 46. Lateral view of right pelvis. Key: D, acetabulum; E, iliac crest; F, symphysis pubis; G, ischial tuberosity; H, obturator foramen; J, ischial spine; 1, sartorius (origin); 5, adductor femoris (origin); 5A, adductor longus (origin); 7, rectus femoris (origin); 9, gluteus maximus (origin); 12, biceps femoris (origin); 16, gluteus medius (origin); 18, gluteus minimus (origin); 19, piriformis (origin); 20, gemelli (origin); 21, obturator externus (origin).





32. **Popliteus.**

This is a large posterior muscle of the lower leg connecting the femur with the tibia. The muscle lies beneath the medial head of the gastrocnemius (24).

ORIGIN. The origin of this muscle is by a very strong tendon in the lateral aspect of the distal femur, adjacent to the lateral condylar articular surface and distal to the tendon of origin of the extensor digitorum longus (27). The tendon lies transverse to the axis of the femur; it passes posteriorly under the lateral collateral ligament of the knee and over the lateral semilunar cartilage and joint capsule. Reaching the posterior aspect of the knee, the tendon spreads rapidly into a large triangular-shaped muscle which immediately starts its insertion into the posteromedial aspect of the upper tibia. The lateral side of the muscle parallels and overlaps somewhat the tibialis posterior (34) and the flexor hallucis longus (35).

INSERTION. Muscular fibers insert on the medial side of the posterior aspect of the tibia, starting at joint level and passing diagonally medially from the mid-upper tibia to a point distally and medially a distance one-fourth from the distal end of the tibia.

ACTION. This would be a strong medial rotator of the tibia and a flexor of the knee.

33. Dr. Howard's notes state "Not found" after the number '33.' Editor.

THE ORIGIN OF THE DEEP POSTERIOR MUSCULATURE

The tibialis posterior (34), the flexor hallucis longus (35), and the flexor digitorum longus (36) form a more or less common combined origin from the full length of the posterior aspect of the fibula, the interosseus membrane, and the distal posterior surface of the tibia. Intercommunicating fibers exist for all three muscles.

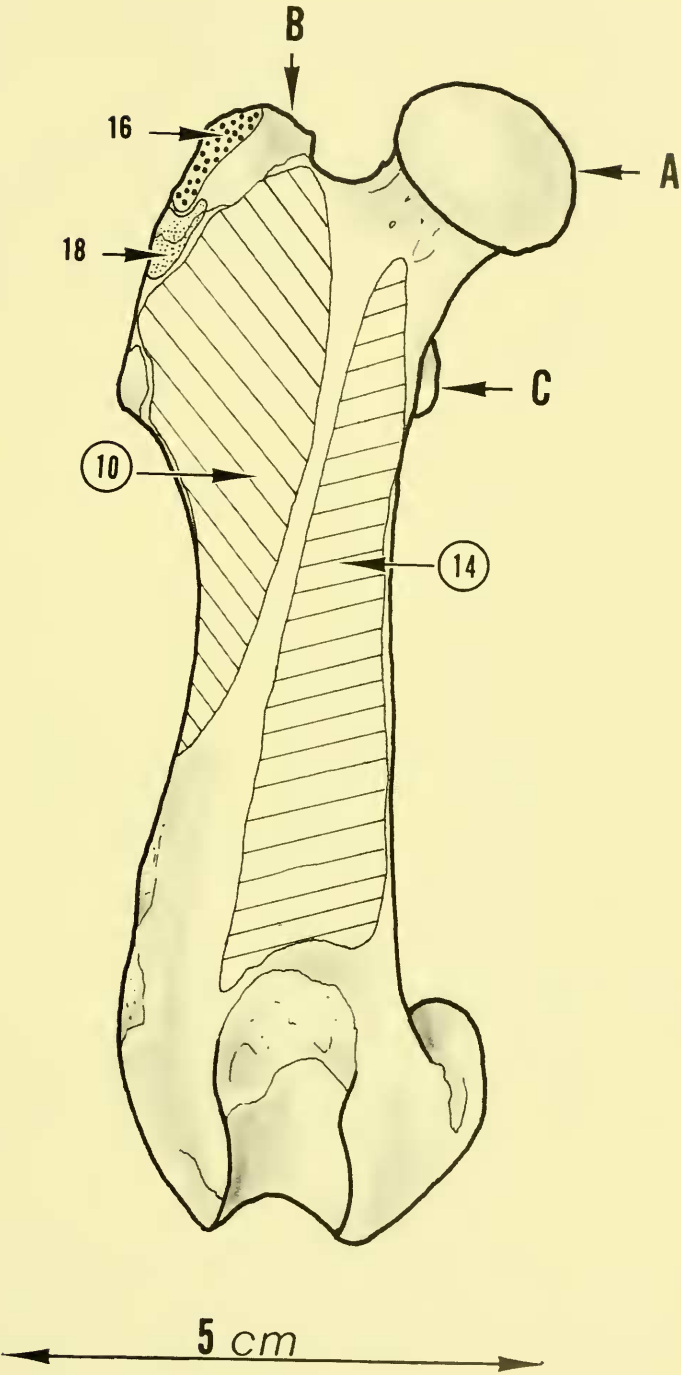
The fibers of origin of the tibialis posterior (34) rise mainly from the head of the fibula, interosseus membrane, and lower tibia.

The fibers of origin of the flexor hallucis longus (35) come mainly from the posterior surface of the head of the fibula, medial to and overlying those of the tibialis posterior (34).

The fibers of origin of the flexor digitorum longus (36) arise mainly from the posterior aspect of the fibula for its full length and the adjacent interosseus membrane.

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FIGURE 47. Anterior view of the right femur. Key: A, head of femur; B, greater trochanter of femur; C, lesser trochanter of femur; 10, vastus lateralis (origin); 14, vastus medialis (origin); 16, gluteus medius; 18, gluteus minimus.



The fiber interdigitation of these muscles is mainly in the upper two-thirds. The tendon of each develops in the lower one-third.

34. *Tibialis posterior.*

This is a deep muscle in the posterior aspect of the lower leg connecting the leg to the foot.

ORIGIN. Muscular fibers are mainly from the head of the fibula and lower end of the tibia and interosseus membrane. Near the ankle, a tendon forms that is most medial and close along that of the flexor hallucis longus (35). The tendon passes around the medial malleolus with a sheath in common with the flexor hallucis longus (35).

INSERTION. The tendon flattens somewhat as it passes distally to the base of the first metatarsal, inserting into the plantar aspect of the proximal end of this bone.

ACTION. The action is plantar flexion of the ankle and foot.

35. *Flexor hallucis longus.*

This is a slender muscle passing from the lower leg to the first toe.

ORIGIN. The origin is mainly by muscular fibers from the head of the fibula on the medial side of the posterior aspect. The origin is closely associated with the tibialis posterior (34) until the tendon starts to form. The tendon parallels that of the tibialis posterior (34) and passes around the medial malleolus in the same sheath. Just distal to the talus, the tendon joins with the flexor digitorum longus (36), but shortly thereafter again becomes a separate tendon passing down the line of metatarsal 1 to enter the fibrous flexor tendon sheath at the metatarsal phalangeal joint level. At this point distally, the tendon passes within the sheath to its insertion on the ventral lip of the distal phalanx adjacent to the articular surface.

ACTION. Flexion of the proximal and distal joints of digit 1.

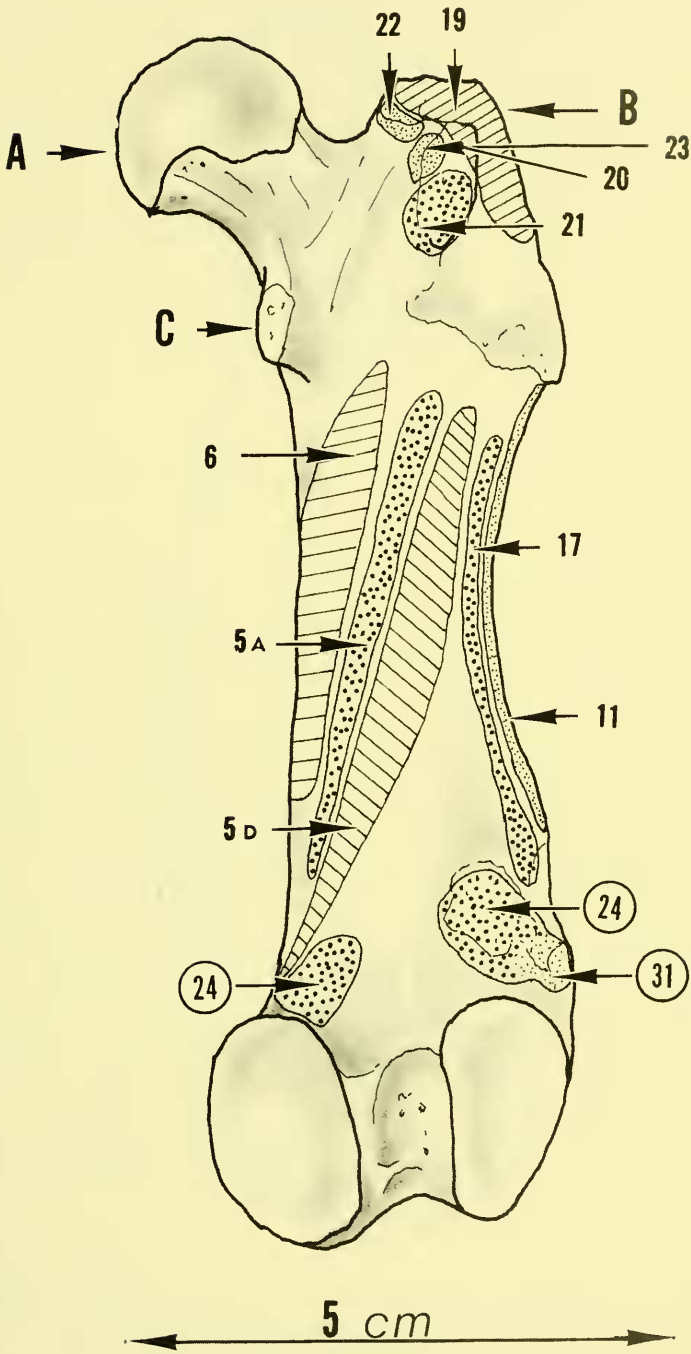
36. *Flexor digitorum longus.*

This is a deep posterior muscle connecting the lower leg to the digits.

ORIGIN. The origin is mainly by muscular fibers from the posteromedial aspect of the fibula for its full length and adjacent interosseus membrane. The muscle broadens distally and abruptly narrows into a tendon at ankle joint level. The tendon then passes through the groove in the posterior talus

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FIGURE 48. Posterior view of right femur. Key: A, head of femur; B, greater trochanter; C, lesser trochanter; 5A, adductor longus; 5D, adductor femoris (deep portion); 6, pectineus; 11, caudofemoralis; 17, presemimembranosus; 19, piriformis; 20, gemelli; 21, obturator externus; 22, iliocapsularis; 23, obturator internus; 24, gastrocnemius (medial and lateral heads—origins); 31, plantaris (portion of origin).



to join the tendon of the flexor hallucis longus (35) as both emerge into the sole of the foot at the distal medial side end of the calcaneus. Here, interdigitation of fibers occurs for a short distance. The flexor hallucis longus (35) then again separates and passes down the line of the first metatarsal to the proximal or metatarsal interphalangeal joint level. The remaining tendon (flexor digitorum longus) continues into the sole of the foot, underlying the flexor digitorum brevis (37). From the area of interdigitation with the flexor hallucis longus (35) to just beyond the calcaneal-cuboid articulation, the long digital flexors join from the lateral side by the musculotendinous fibers of the short, flat, and broad quadratus plantae (38).

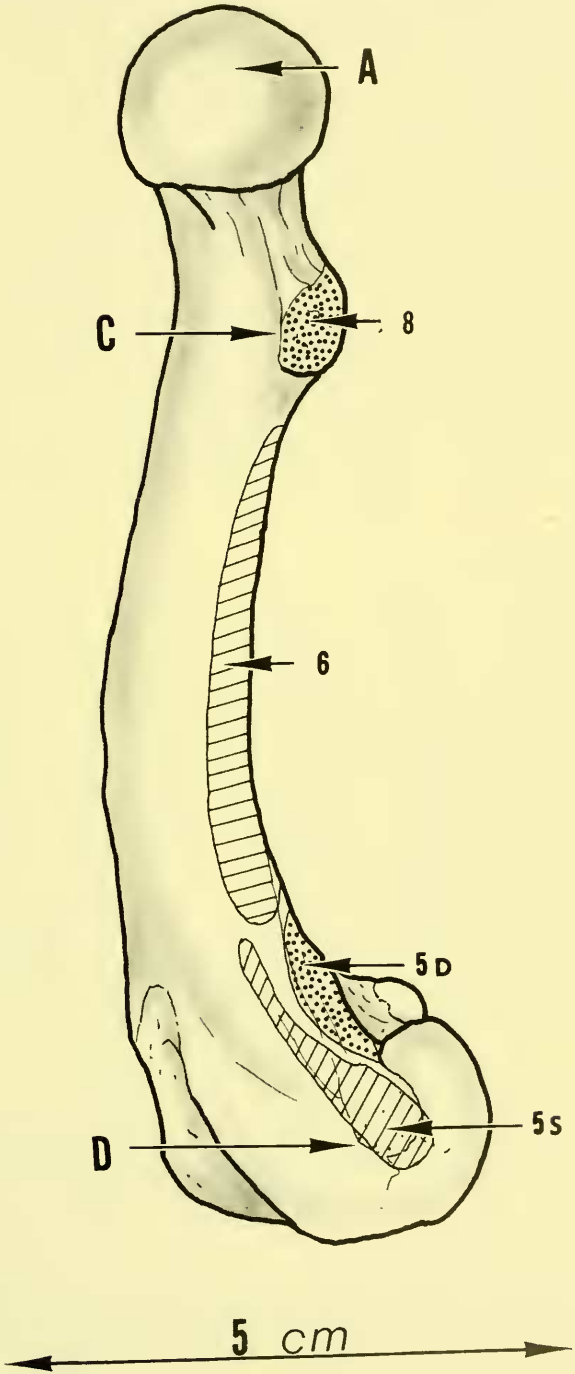
37. Flexor digitorum brevis.

This muscle develops the connection with the plantaris (31) tendon as it appears in the sole of the foot.

ORIGIN. As the plantaris tendon (31) enters the sole of the foot from the groove in the calcaneus, it expands into a musculotendinous structure (flexor digitorum brevis) (37). This structure is superficial and occupies or covers much of the proximal foot in a manner similar to a plantar fascia. Distally at about the half-way point of the sole, the musculotendinous mass separates into four slightly flattened tendons which proceed fan-like to the metacarpal head areas of digits 2, 3, 4, and 5. At this point, each tendon directly overlies the flexor digitorum longus (36) tendon, and together they enter the flexor tendon sheath which extends for the full length of the digit. This flexor tendon sheath is a fibrous connective tissue tunnel with transverse reinforcements (termed pulleys) at proximal and middle joint levels. The pulleys and sheath act to prevent bowstringing of the flexor tendons as the digits are flexed. At proximal joint level, the flexor digitorum brevis forms a sling-like structure which completely surrounds the profundus tendon for a short distance and holds the two tendons in close proximity. Just within the flexor tendon sheath, the tendon splits and assumes a more dorsal position, which permits the flexor digitorum longus (36) to become superficial. Continuing on either side of the flexor digitorum longus (36), the flexor brevis now passes with the longus under the distal flexor tendon sheath pulley at proximal interphalangeal joint level. Each half of the tendon then broadens. The two halves join together deep to the flexor digitorum longus, forming a flat tendon which inserts into the ventral lip of the middle phalanx at proximal interphalangeal joint level. Vincula are present as the tendon approaches its insertion.

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FIGURE 49. Medial view of right femur. Key: A, head of femur; C, lesser trochanter of femur; D, medial epicondyle of femur; 5S, adductor femoris (superficial portion); 5D, adductor femoris (deep portion); 6, pectineus; 8, iliopsoas.



ACTION. The tendon of the flexor digitorum brevis can serve to flex independently the proximal interphalangeal joint, but can flex the metatarsal phalangeal joint as well.

38. *Quadratus plantae*.

This is a short, broad, flat muscle joining the calcaneus to the flexor digitorum longus (36) tendons.

ORIGIN. This muscle arises from the lateral aspect of the calcaneus for its full length. The muscle triangulates somewhat, passing distally and covering most of the plantar surface of the distal one-half of the calcaneus on its plantar aspect. Mostly fleshy fibers then join the flexor digitorum longus tendon (36) just opposite where the flexor hallucis longus (35) tendon also joins, and just proximal to the point of division of the flexor digitorum longus (36) into the separate tendons which pass to digits 2, 3, 4, and 5.

ACTION. The exact function of this muscle is not clear, but it probably aids in holding the long digital flexors laterally during the time that they are contracting.

39. *Calcaneometatarsalis*.

This is an extremely small muscle overlying the quadratus plantae (38), joining the calcaneus with the proximal end of the fifth metatarsal.

ORIGIN. This muscle arises from the small area on the posterolateral aspect of the calcaneus immediately adjacent to the point of exit of the plantaris (31) tendon. This small muscle then tapers as it passes obliquely over the quadratus plantae (38) toward the base of metatarsal five. A thin tendon forms at the distal one-third, continues distally, and overlies the peroneus longus tendon (28) where it dips deeply into the sole, then underlies the medial side of the peroneus brevis (30).

INSERTION. This tiny tendon then inserts into the base of the fifth metatarsal just proximal to the insertion of the peroneus brevis (30).

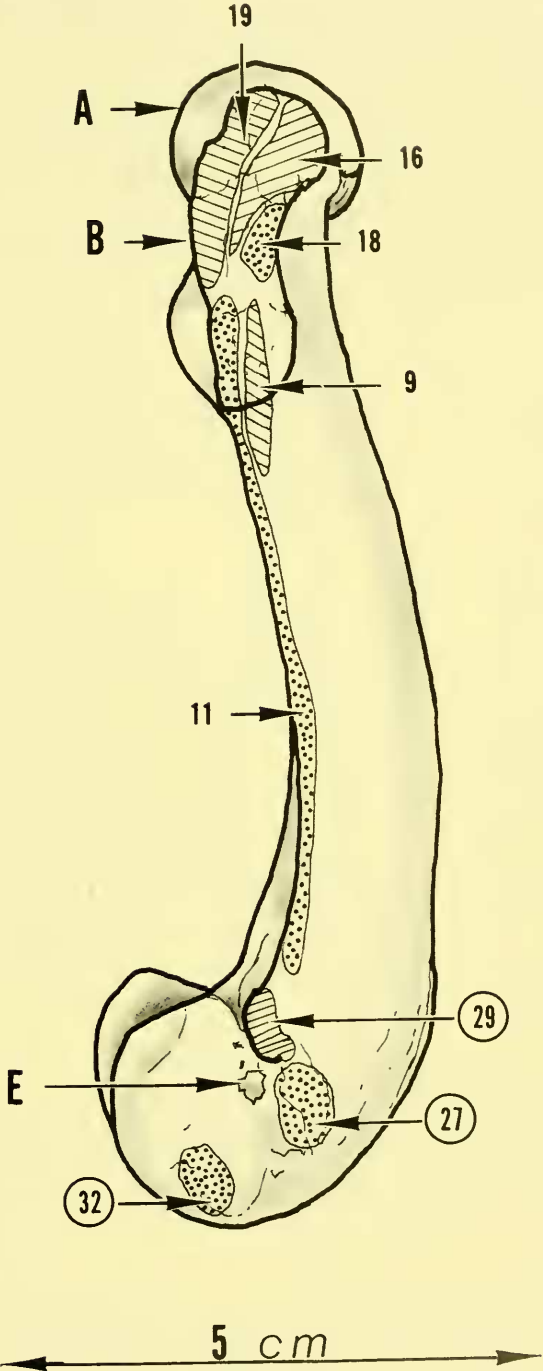
ACTION. Just what the action of this muscle is would be difficult to determine. From the standpoint of origin and insertion, the muscle could support the longitudinal arch of the foot.

THE INTRINSIC MUSCLES OF THE FOOT

This group of small muscles has origin and insertion within the foot proper. They serve to balance the action of the longer and more powerful prime movers

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FIGURE 50. Lateral view of right femur. Key: A, head of femur; B, greater trochanter of femur; E, attachment of lateral collateral ligament of knee; 9, gluteus maximus; 11, caudofemoralis; 16, gluteus medius; 18, gluteus minimus; 19, piriformis; 27, extensor digitorum longus (origin); 29, peroneus digiti quinti (origin); 32, popliteus (origin).



of the digits, and to give finer and more individualized skill motions to the digits. The broad webbing and elongated digits of the hind limb, as compared to the forelimb, permits more individualized digital motions.

The intrinsic muscles fall into three groups for descriptive purposes: the lumbrical muscles (48) which arise from the flexor digitorum longus (36) in the foot, the small muscles grouped about the first and fifth metatarsals, and the deeply situated interossei musculature (46).

The extensor digitorum brevis (47), although its origin and insertion are within the foot, is not considered an intrinsic muscle, but it is described in this general group for convenience.

INTRINSIC MUSCLES OF THE FIFTH DIGIT (40, 41, 42)

The fifth digit in the sea otter is the largest, and therefore the small muscles about this digit have a greater total volume than those about the first digit. The opponens muscle (42) is very small and, in view of its insertion, could hardly be expected to give opposition to this digit.

40. *Abductor digiti quinti*.

This is one of the three small muscles grouped about the fifth metatarsal.

ORIGIN. This largest of the small foot muscles is the most lateral in location. The muscle arises proximally from the heavy ligamentous capsule and small sesamoid bone overlying the plantar aspect of the base of the fifth metatarsal on the medial side and from the base of the metatarsal laterally adjacent to the insertion of the peroneus brevis (30). The origin continues distally from the lateral side of the fifth metatarsal for its full length. The muscle passes somewhat obliquely across the plantar surface of the fifth metatarsal, covering most of the ventral surface of the bone. At the metatarsal head, a short broad tendon develops which blends into the joint capsule, making attachments to the lateral sesamoid and the base of the proximal phalanx on its lateral side.

ACTION. This muscle serves to abduct and flex the proximal joint of the fifth digit.

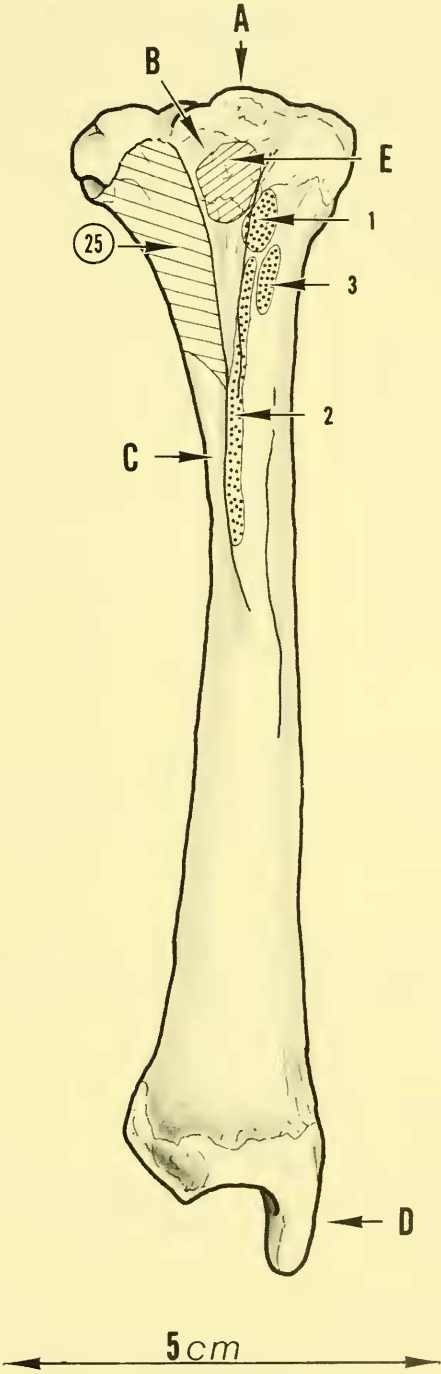
41. *Adductor digiti quinti*.

This muscle is located opposite the abductor (40) and opposes its action.

ORIGIN. This muscle is considerably smaller than the abductor (40). It takes its origin from the capsular structures just medial to the abductor (40)

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FIGURE 51. Anterior view of right tibia. Key: A, tibial plateau; B, tibial tuberosity; C, tibial crest; D, medial malleolus; E, patella tendon (combined tendons of 7, 10, and 14); 1, sartorius; 2, gracilis; 3, semitendinosus; 25, tibialis anterior (origin).



and also from the medial side of the fifth metatarsal shaft in its proximal one-half. The muscle then courses distally to the medial side of the proximal joint where a short flattened tendon develops.

INSERTION. This tendon blends into the joint capsule, attaching to the medial sesamoid to make its insertion into the base of the proximal phalanx on the medial plantar aspect. Distally, the thin tendon of the opponens digiti quinti (42) courses over the tendinous expansion.

ACTION. This muscle serves to adduct and flex the proximal joint of the fifth digit.

42. *Opponens digiti quinti.*

This is a small intrinsic muscle and from its position is given the name opponens.

ORIGIN. The muscle arises from the midcentral area of the fibrous capsule of the tarsus and superficially overlies the proximal origin of all interossei (46) except the most medial one. The muscle tapers promptly into a very thin tendon at the level of the junction of the middle and proximal thirds of the fourth metatarsal. The tendon then continues obliquely toward the medial side of the proximal joint of the fifth digit. Keeping to the medial side, the tendon passes over the tendon of the adductor hallucis (44) and appears to join into the extensor aponeurosis one-third of the way down the proximal phalanx.

ACTION. This small muscle could assist in flexion of the proximal joint, adduction of the proximal joint, and possibly to the extensor aponeurosis, giving some assistance in the extension of the middle and distal joints. In spite of its name, its insertion would exclude any opposition motion of the fifth digit.

INTRINSIC MUSCLES OF THE FIRST DIGIT (43, 44)

The first digit with its two phalanges is the shortest toe in the foot, and the two associated intrinsic muscles are likewise small. There is no opponens muscle for this digit.

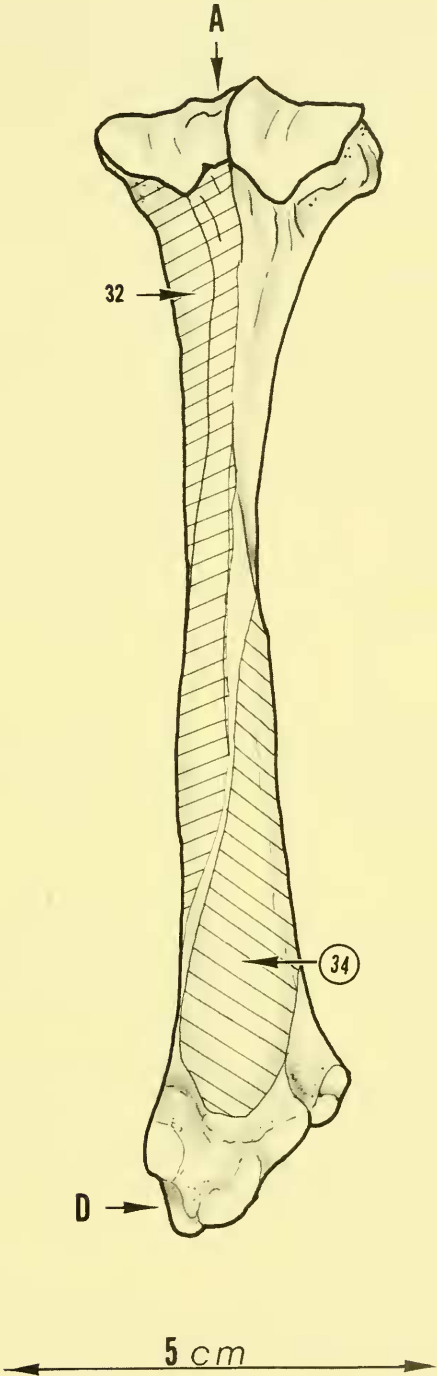
43. *Abductor hallucis.*

This muscle is the most medial of the small foot muscles.

ORIGIN. This muscle arises from the fibrous plantar capsule of the tarsus at the base of the first metatarsal. The muscle is fusiform in shape and passes

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FIGURE 52. Posterior view of right tibia. Key: A, tibial plateau; D, tibia (medial malleolus); 32, popliteus; 34, tibialis posterior (origin).



distally overlying the medial one-half of the first metatarsal. A short flat tendon develops just proximal to the proximal joint level and passes medially over the medial sesamoid to which it has fibrous attachment, then continues in an aponeurosis-like structure to the base and side of the proximal phalanx for its insertion.

ACTION. Flexion of the proximal joint and abduction of the proximal joint of digit one.

44. Adductor hallucis.

ORIGIN. This small fusiform muscle and companion of the abductor (43) arises from the fibrous plantar capsule on the lateral side of the base of metatarsal one. Proceeding distally and parallel to the abductor, it overlies the lateral one-half of metatarsal one on its ventral surface. Distally, a short flat tendon develops which passes to the lateral side, inserting in a similar manner to the abductor. Fibrous attachments are present to the lateral sesamoid and joint capsular structures, and eventually insertion is into the proximal side of the proximal phalanx.

ACTION. Flexion and adduction of the proximal joint of digit one.

45. Dr. Howard omitted mention of any muscle numbered '45.' Editor.

THE INTEROSSEI MUSCULATURE

The interossei muscles are six in number. They lie deep in the sole of the foot, being cradled in the transverse metatarsal arch. There are two interossei for each of digits two, three, and four, and they insert respectively on the medial and lateral sides of the digits.

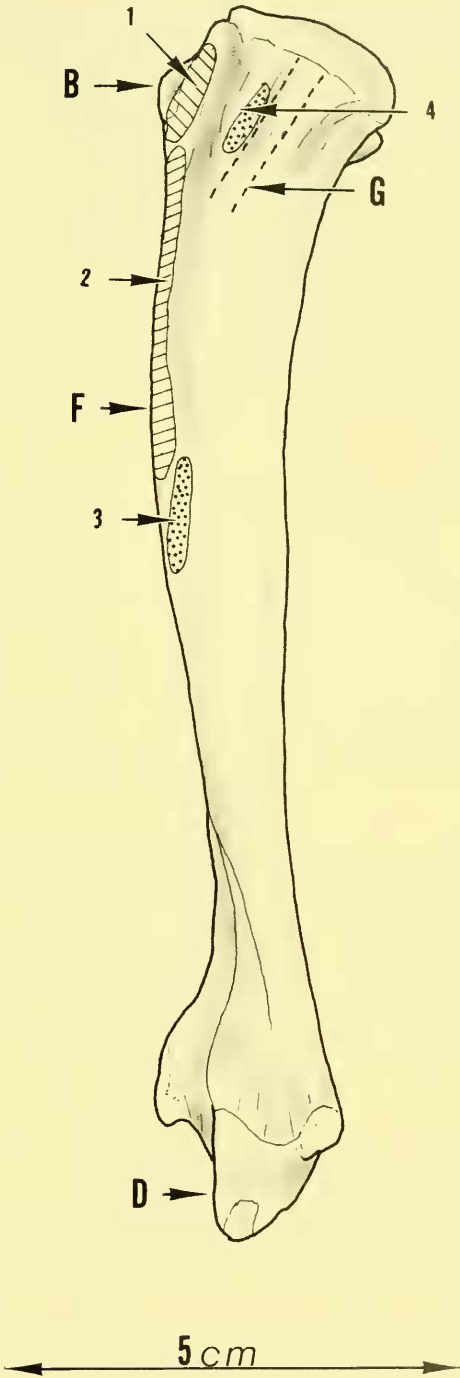
46. Interossei.

Excluding the small muscles about the first and the fifth digits, there are six small interossei muscles: two each for digits two, three, and four. For descriptive purposes, they can be identified from the medial to the lateral side as 46a-f.

ORIGIN. The interossei muscles arise in sequence from the heavy fascia covering the plantar surface of the tarsus, from the lateral side of the base of metatarsal one to the medial side of the base of metatarsal five. Muscle fibers also arise from the periosteum of the proximal ends of the metatarsal. The origin of 46a and b overlies the proximal end of metatarsal two. The origin

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FIGURE 53. Medial view of right tibia. Key: B, tibial tubercle; D, medial malleolus of tibia; F, anterior crest of tibia; G, medial collateral ligament; 1, sartorius; 2, gracilis; 3, semitendinosus; 4, semimembranosus.



of 46c and d overlies the proximal end of metatarsal three. The origin of metatarsal 46e and f overlies the proximal end of metatarsal four, with some additional overlapping of f onto the proximal end of metatarsal five.

INSERTION. The muscles pass distally to assume their respective positions on either side of metatarsals two, three, and four. Near the metatarsophalangeal joint, flat tendons form which spread out with attachments to the joint capsule and adjacent sesamoid in a more ventral area, and the more dorsal area of tendon extends distally and dorsally into the extensor hood to join the extensor aponeurosis of the digit.

ACTION. The action of the interossei muscles is to flex the metatarsophalangeal joint and to give a degree of lateral motion at this joint. Also, through the lateral bands, these muscles would act to extend the middle and distal interphalangeal joints.

47. *Extensor digitorum brevis.*

This muscle is an accessory digital extensor which lies deep to the extensor digitorum longus (27) and joins the ankle area with the digits.

ORIGIN. This muscle arises from the calcaneus and adjacent capsular structures on the dorsolateral aspect of the ankle. The origin lies directly under the extensor digitorum longus (27) tendons where they pass through the sheath in front of the ankle. Three distinct muscle bellies are present, and these extend distally to about the metatarsal junction of digits five, four, and three. The muscle terminates in three long flat tendons which pass to the ulnar sides of digits four, three, and two where they enter the hood structure and extensor aponeurosis.

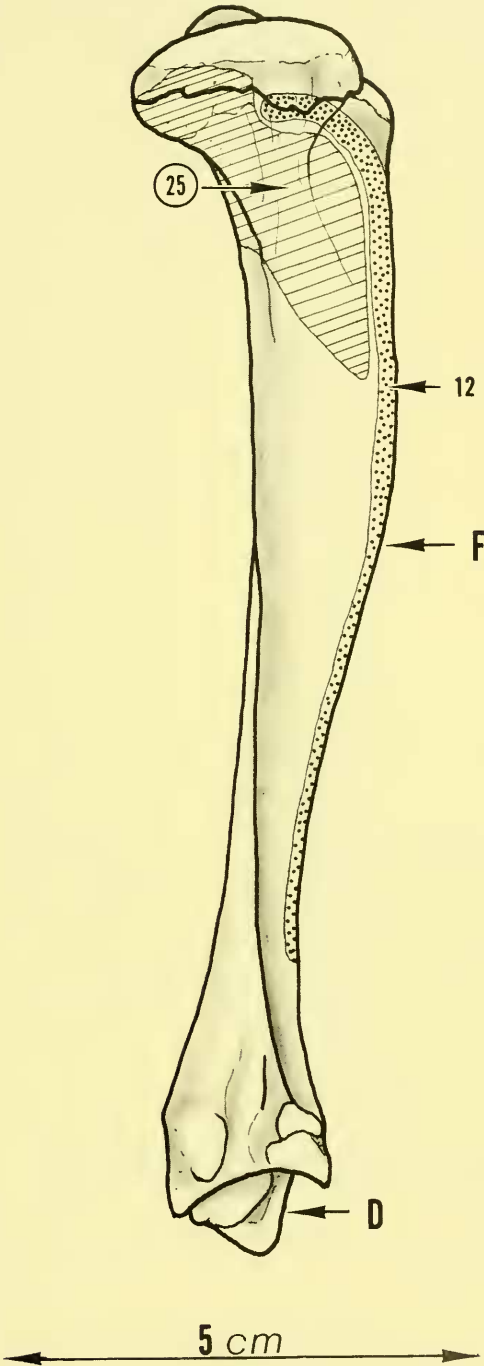
INSERTION. These tendons enter the extensor aponeurosis to the ulnar side of the extensor digitorum longus (27) and the tendinous fibers continue distally to form a generally lateral border of the aponeurosis. At the interphalangeal joint level, the fibers are generally central with those of the longus, and the insertion is into the base of the middle phalanx. Tendinous fibers may continue to form, in part at least, the extensor tendon going to the distal joint. In the specimen dissected, there arose from the medial and lateral muscles tiny

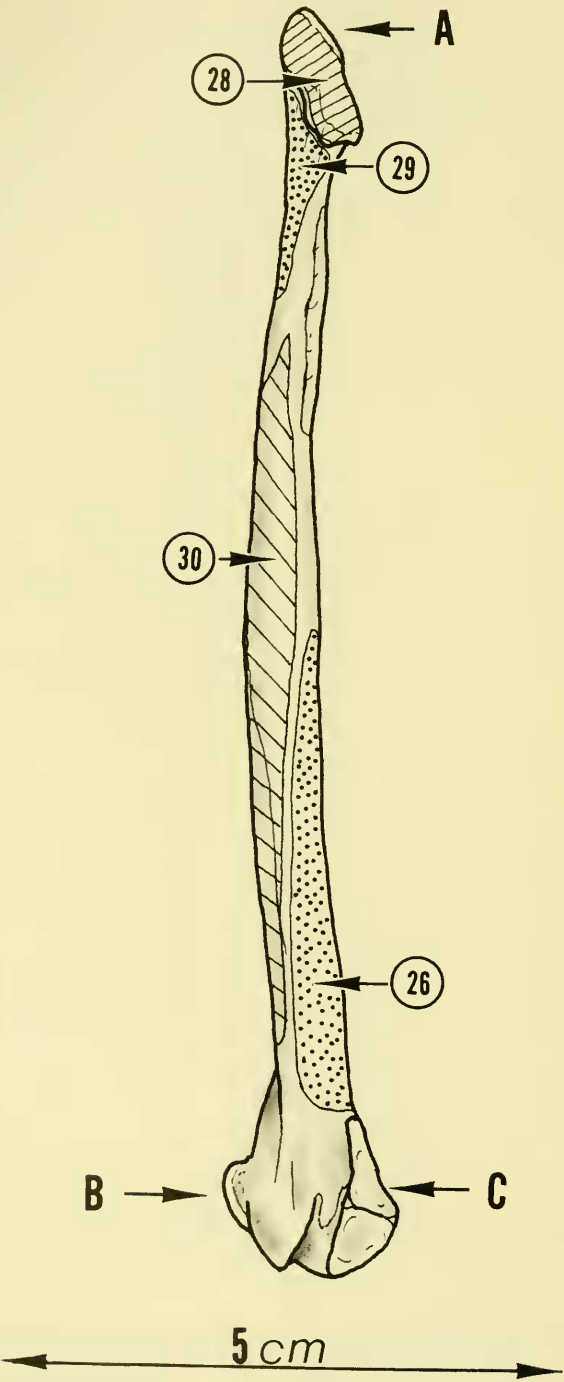
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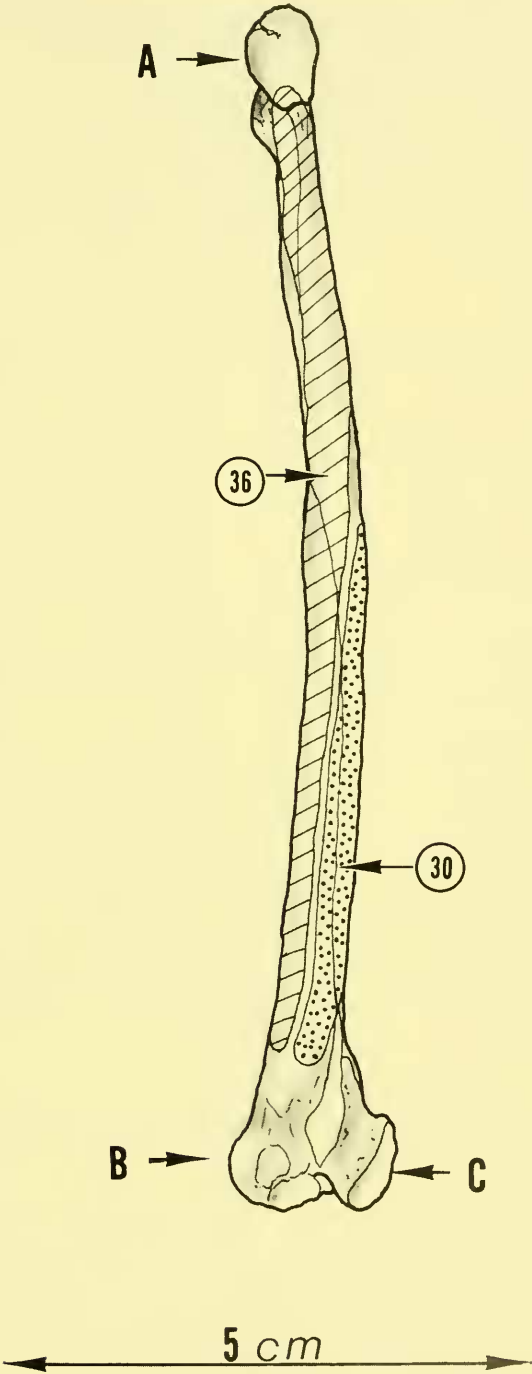
FIGURE 54. Lateral view of right tibia. Key: D, medial malleolus of tibia; F, tibial crest; 12, biceps femoris; 25, tibialis anterior (origin).

FIGURE 55. Anterior view of right fibula. Key: A, head of fibula; B, lateral malleolus; C, articulation with tibia; 26, extensor hallucis longus (proprius—origin); 28, peroneus longus (origin); 29, peroneus digiti quinti (anterior head—origin); 30, peroneus brevis (origin).

FIGURE 56. Posterior view of right fibula. Key: A, head of fibula; B, lateral malleolus; C, articulation with tibia; 30, peroneus brevis (origin); 36, flexor digitorum longus (origin).







tendinous slips which joined respectively with the extensor digitorum longus (27) of the fifth and the extensor hallucis proprius (26) of the first. It is highly probable that individual variations occur.

ACTION. The tiny tendinous slips that go to the first and fifth digits are so small that the function would be minimal, if any. For the main tendons going to digits two, three, and four the action would be the same as the extensor digitorum longus (27), as both are acting through the extensor aponeurosis of the digits.

48. **Lumbricales.**

These small slender muscles arise from the long flexor tendons of digits two, three, four, and five, and are generally included in the intrinsic muscle group.

ORIGIN. Out of a total of six muscles, four follow a basic pattern of arising from the radial side of each flexor tendon (flexor digitorum longus—36) for each of the digits two, three, four, and five. They are thin fusiform muscles, each forming a small thin tendon just proximal to the metatarsophalangeal joint level on the radial side of each digit. The other two more superficial muscles arise more from the ventral surfaces of the flexor digitorum longus (36) tendon of four and five. They are closely associated proximally, but separate distally into two distinct muscles. Each forms a thin tendon, the more medial one passing toward the fourth digit and the more lateral toward the fifth digit.

INSERTION. Of the four lumbricales arising from the basic pattern, each has a thin long tendon which goes respectively to the radial sides of digits two, three, four, and five. For digits two, three, and four, a slender tendon inserts on the radial side of the proximal phalanx a short distance beyond the proximal joint and ventral to the extensor aponeurosis. For digit five, the tendon joins with the extensor digitorum longus (27) to form the radiolateral margin of the extensor aponeurosis.

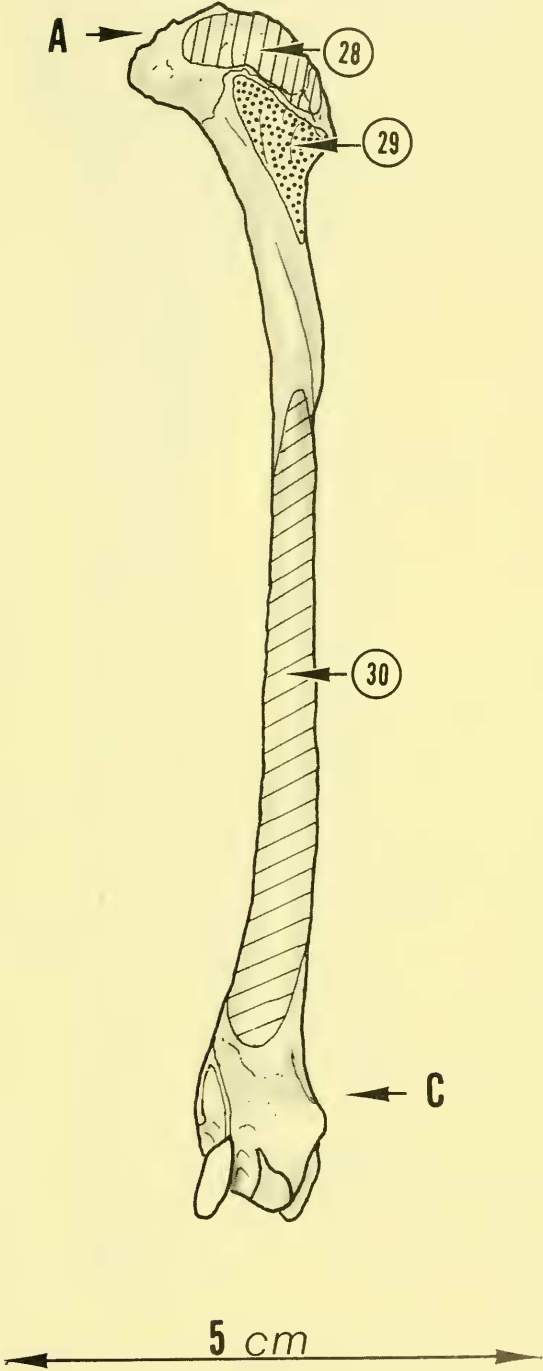
The more superficial lumbrical muscles arising from the long flexor tendons of four and five, are much smaller than the others. Their thin tendons pass

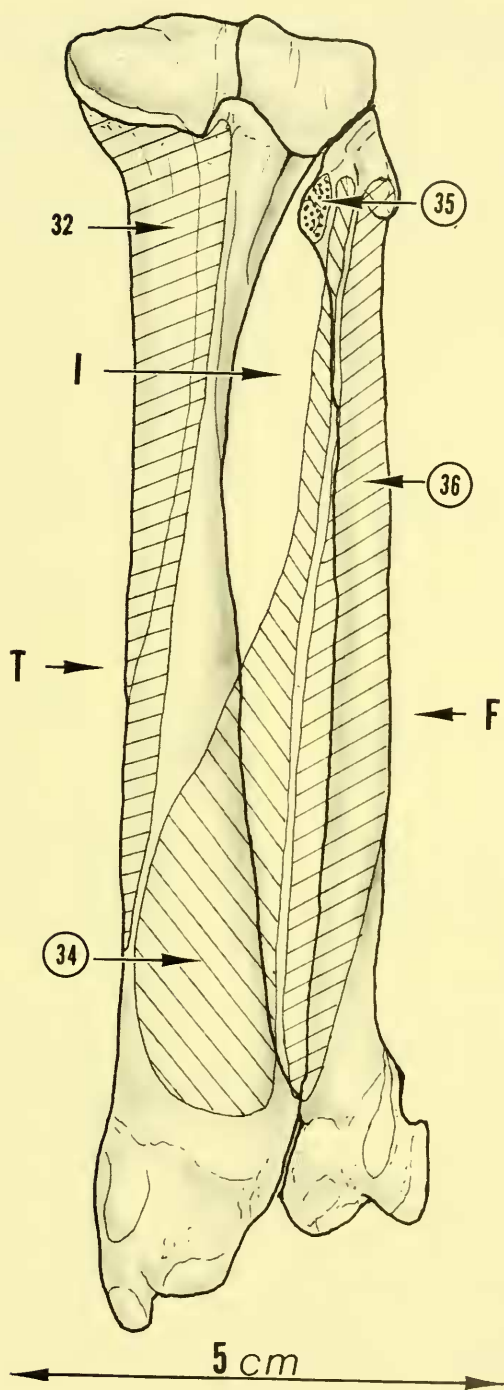
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FIGURE 57. Lateral view of right fibula. Key: A, head of fibula; C, lateral malleolus of fibula; 28, peroneus longus (origin); 29, peroneus digiti quinti (anterior head—origin); 30, peroneus brevis (origin).

FIGURE 58. Anterior view of right tibia and fibula (articulated). Key: T, tibia; F, fibula; I, interosseus membrane; 2, gracilis; 4, semimembranosus; 25, tibialis anterior (origin); 26, extensor hallucis longus (proprius—origin); 28, peroneus longus (origin).

FIGURE 59. Posterior view of the right tibia and fibula (articulated). Key: T, tibia; F, fibula; I, interosseus membrane; 32, popliteus; 34, tibialis posterior; 35, flexor hallucis longus; 36, flexor digitorum longus.





ventrally and join respectively the ulnar sides of the sublimus flexor tendons just prior to their disappearance into the flexor tendon sheath at the metatarsal joint level.

ACTION. The action of the four lumbricales which follow the basic pattern would be to assist in flexion of the metatarsophalangeal joint. They would also give some radial lateral flexion of the joint. The one passing to digit five would also assist in extension of the distal two joints through the extensor aponeurosis. The more superficial lumbrical muscles, which serve to join the profundus and sublimus flexors, undoubtedly have some function but it would be difficult to state just what this function is.

EXTENSOR APONEUROSIS

The extensor mechanism for the digits is complicated and not completely understood. The tendinous flattened structure overlying the dorsum of digits 2 through 5 inclusive provides the mechanical arrangement for the insertion and action of the extrinsic and intrinsic musculature. By extrinsic is meant the extensor digitorum longus (27), the extensor digitorum brevis (47), the extensor hallucis longus (26), and the peroneus digiti quinti (29). By intrinsic musculature is meant the interossei (46) and for digit 5 the lumbrical (48) muscle.

The general plan of this mechanism is as follows: The long tendons of the extrinsic muscles for digits 2, 3, 4, and 5 join at the metatarsophalangeal joint level in a fibrous hood-like structure which marks the beginning of the aponeurosis and which attaches ventrally to the capsular structures on either side. The long tendons do not insert into the proximal phalanx, but act to extend the metatarsophalangeal joint by virtue of this hood-type structure. The aponeurosis now proceeds distally as a continuation of the tendons with the cross fibers, with the addition of the interossei tendons medially and laterally for digits 2, 3, and 4, to form lateral bands: for the fifth digit the lumbrical performs this function on the radial side.

At proximal interphalangeal joint level, direct insertion at the base of the middle phalanx occurs for most of the extensor tendon fibers, but some continue on to insert terminally at the base of the distal phalanx. Both insertions are on the dorsal aspects. The fibers continuing beyond the interphalangeal joint level form a thin and rather poorly developed tendon.

In fresh specimens, traction on the extrinsic tendons will extend all three joints of digits 2, 3, 4, and 5, provided the metatarsophalangeal joint is not permitted to hyperextend. If the metatarsophalangeal joint is allowed to hyperextend, the distal two joints drop into slight flexion as the excursion of the long tendons is limited by the hood attachment. This claw-type deformity is corrected, for the most part, when traction is made along the lateral bands of the aponeurosis.

Although passive hyperextension is present for both proximal and distal interphalangeal joints, active hyperextension is not obtained by traction on the aponeurosis. In fact, the tendon action distal to proximal interphalangeal joint level seems limited and weak.

See figure 41 for a diagrammatic representation of the aponeurosis and the various tendon components for the specimen study. Undoubtedly, variations would be noted if many specimens were to be dissected.

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The State of California Department of Fish and Game was most cooperative in providing the specimen for anatomical study. The California Academy of Sciences provided the invaluable aid of a disarticulated sea otter skeleton.

The Anatomical Studies of the California River Otter, by Edna M. Fisher, proved to be an excellent guide during the dissection, and her unpublished notes on sea otter anatomy, which were made available through the courtesy of Mr. Fred Tarasoff, were also of value. Unpublished notes and sketches by Fred Tarasoff were also available and of some assistance.

The dissection and storage of materials took place at the Hopkins Marine Station of Stanford University in Pacific Grove, California, and the personnel of this institution, particularly Dr. D. Abbott, gave encouragement and assistance in every way possible.

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